Ensemble Experiments based on the convection-allowing model COSMO-DE

Susanne Theis

Project COSMO-DE-EPS

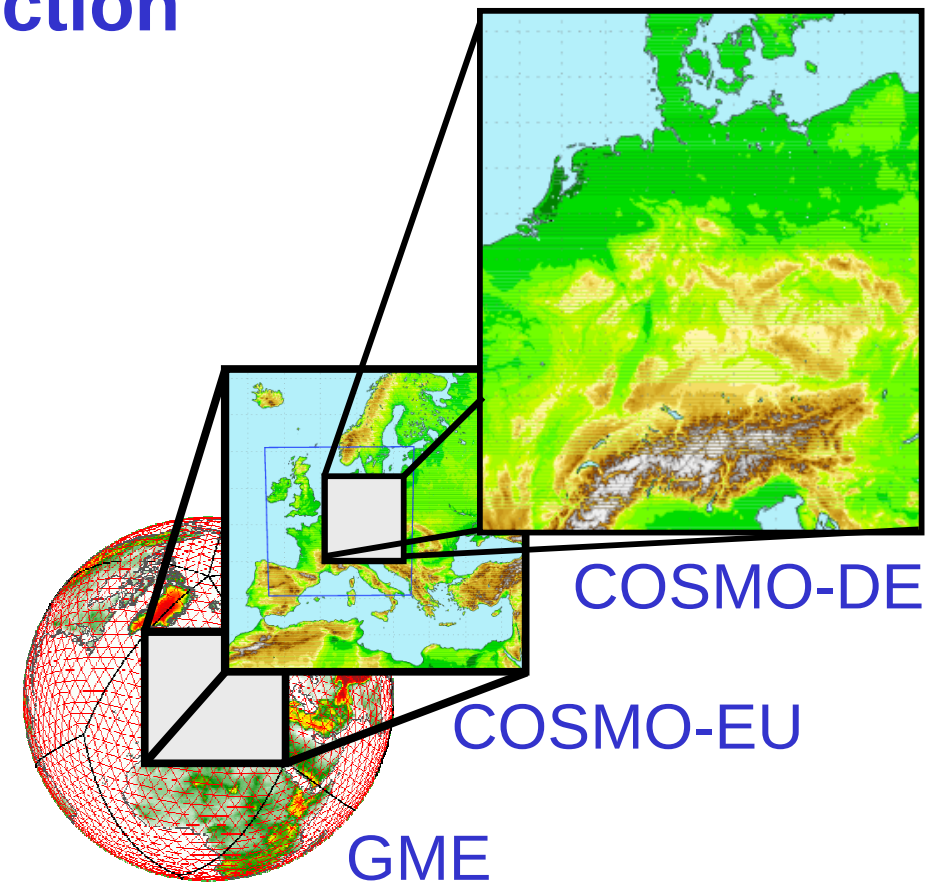
Overview

- Motivation for Project COSMO-DE-EPS
- Tasks within Project
- Current Status and Experiments

Motivation for the Project

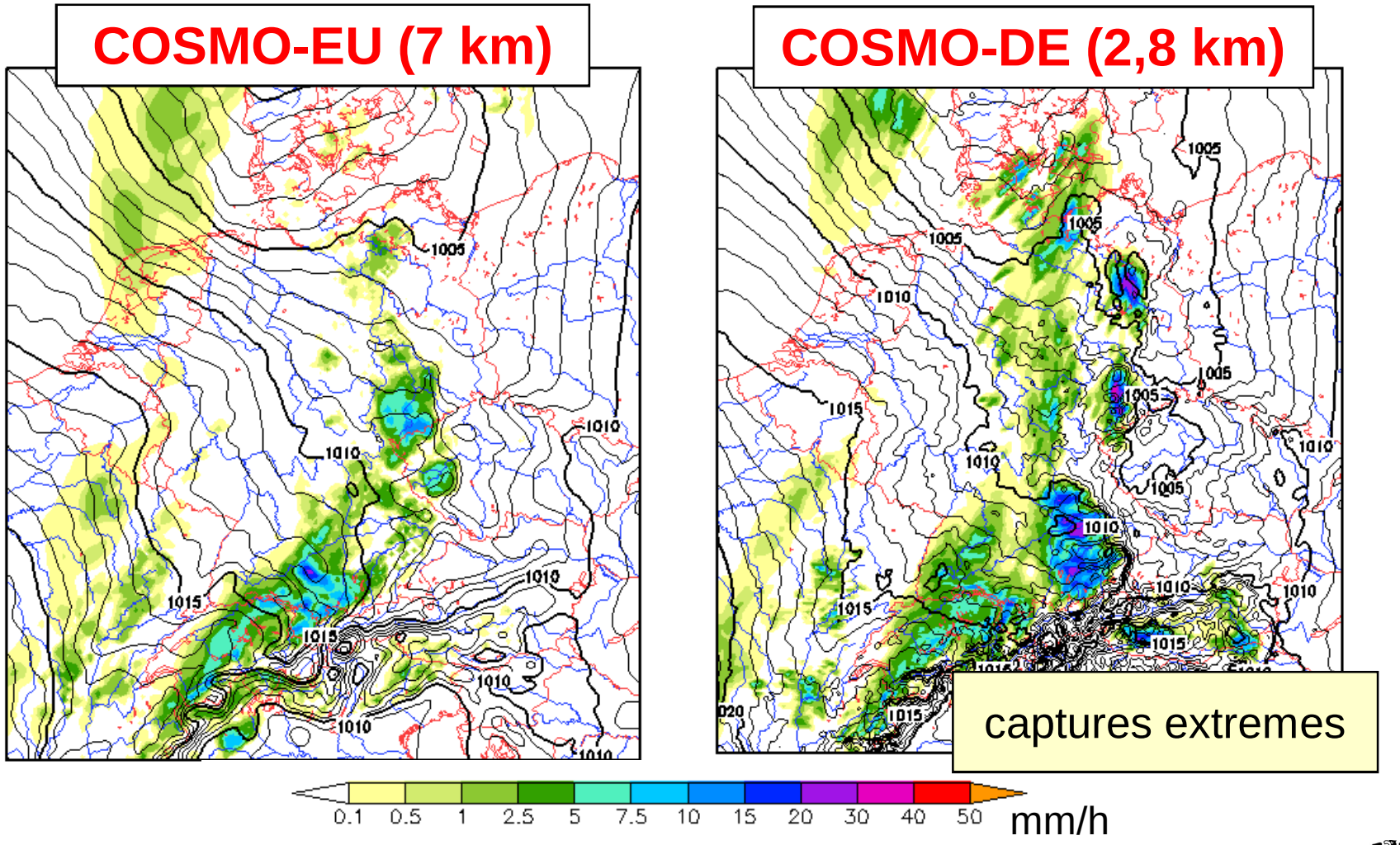
Numerical Weather Prediction Model COSMO-DE

- grid box size: 2,8 km
- without parametrization of deep convection
- assimilation of radar data

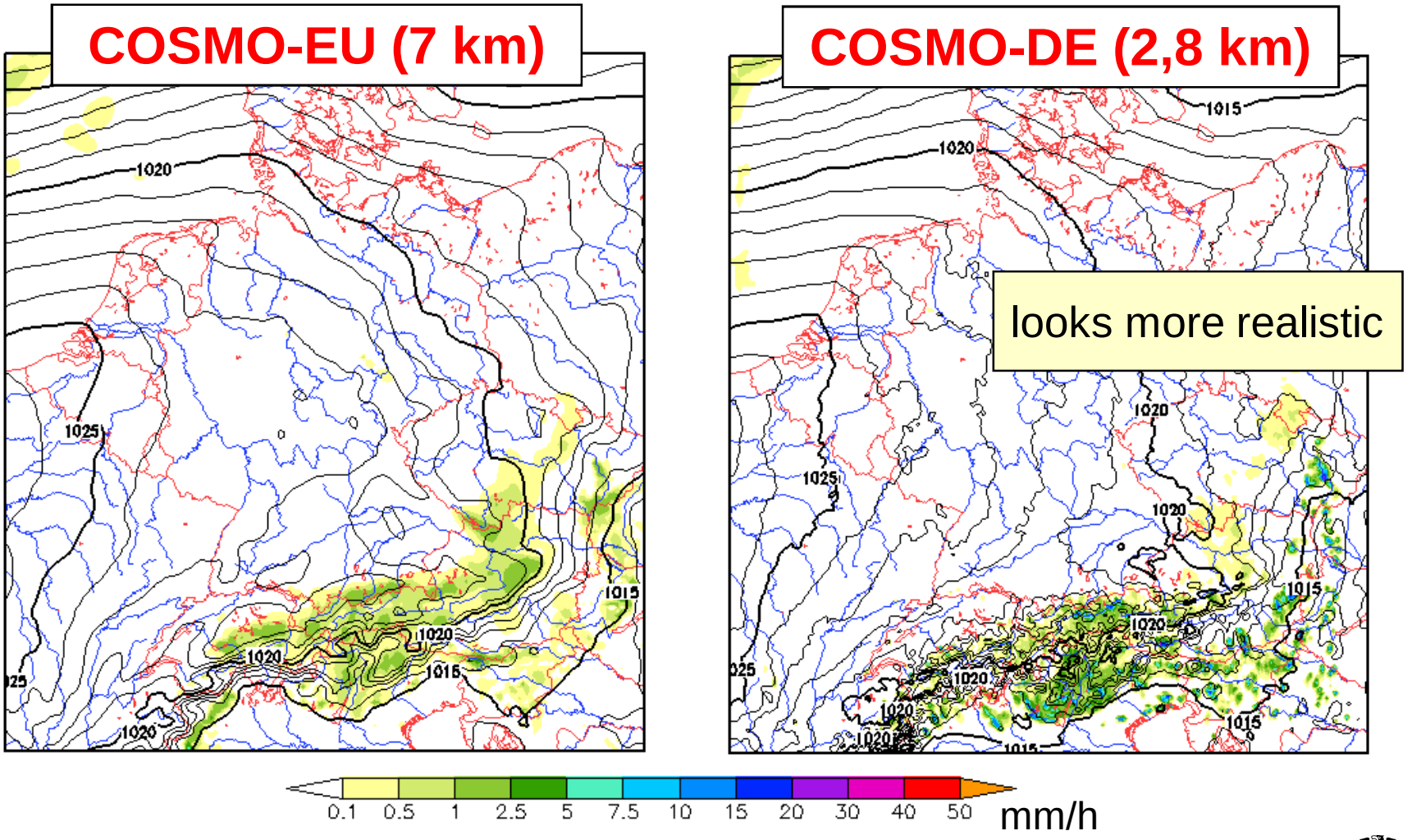


- lead time: 0-21 hours
- operational since April 2007

Benefits of COSMO-DE

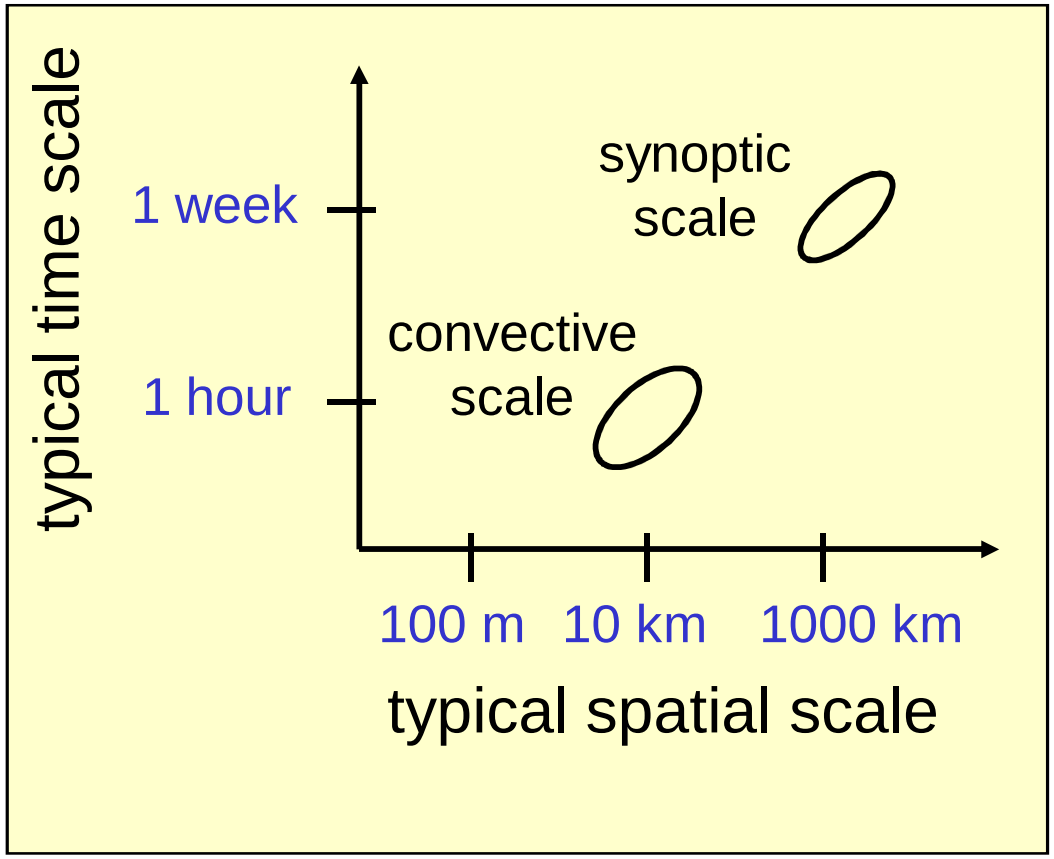


Benefits of COSMO-DE

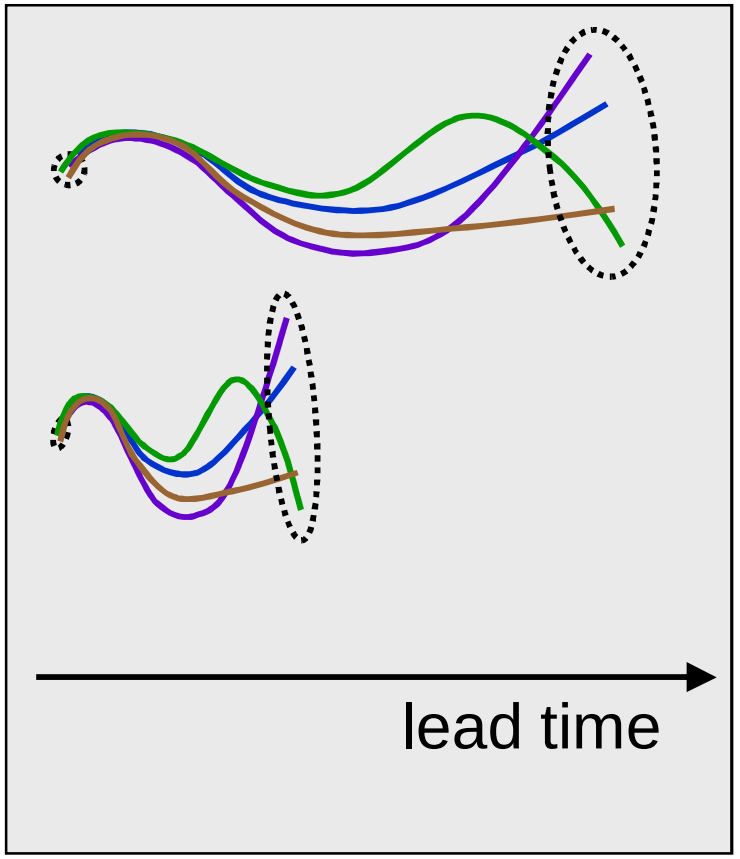


What about Deterministic Predictability?

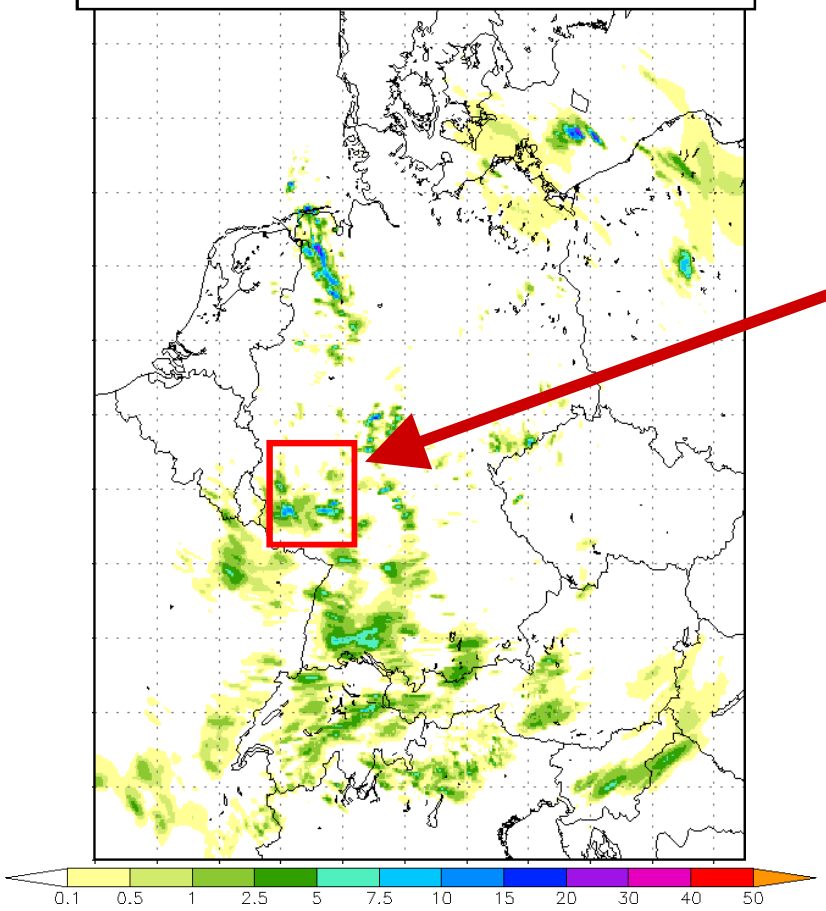
Scale Diagram



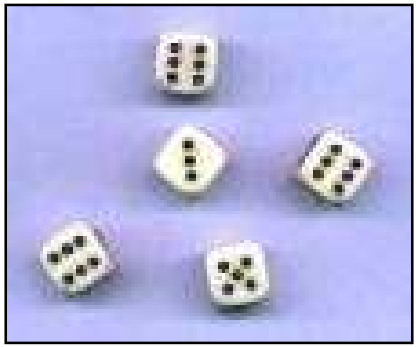
Predictability



COSMO-DE (2,8 km)



mm/h



need for probabilistic approach

→ so that user really gets benefit

Project COSMO-DE-EPS: Development of a convection-allowing Ensemble Prediction System

Susanne Theis, Christoph Gebhardt, Michael Buchhold,
Marcus Paulat, Roland Ohl, Zied Ben Bouallègue, Carlos Peralta

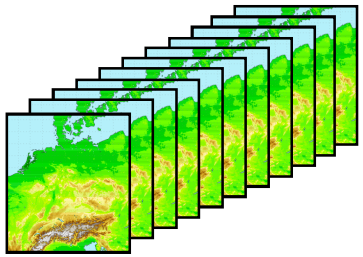
Project COSMO-DE-EPS:

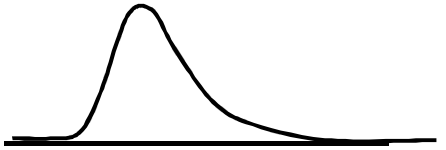
Development of a convection-allowing Ensemble Prediction System

Aims & Tasks

Setting up an Ensemble System

„variations“ in prediction system





ensemble products:

- probability density fct
- exceedance probs
- quantiles
- „spread“
- mean
- ...

several predictions
= „members“ of ensemble

→ *very large investment in computing power*

Aim of the Project

How many ensemble members?

20 members, pre-operational

40 members, operational

When?

2010 pre-operational

2011 operational

Aim of the Project

How many ensemble members?

20 members, pre-operational

40 members, operational

When?

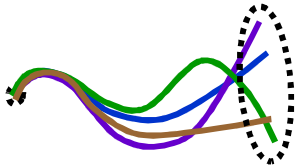
2010 pre-operational

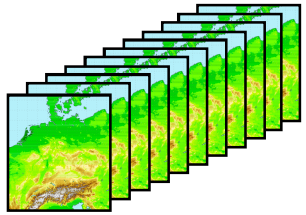
2011 operational

conditional on supercomputer

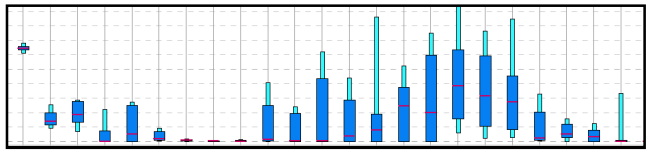
Tasks within Project

- implementation of perturbations





- verification & diagnostics
- post-processing
- visualization
- early user feedback



Implementation of Perturbations

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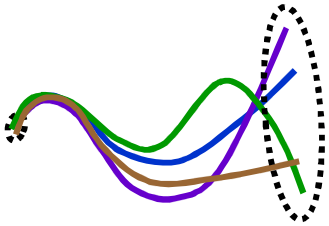
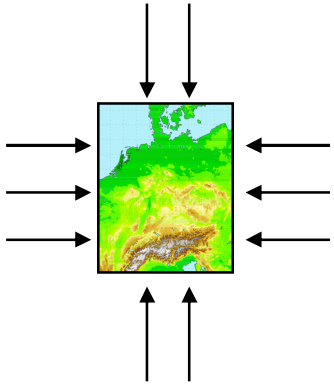


x



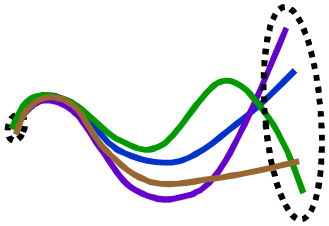
x

initial conditions

boundary conditions

model physics

Implementation of Perturbations



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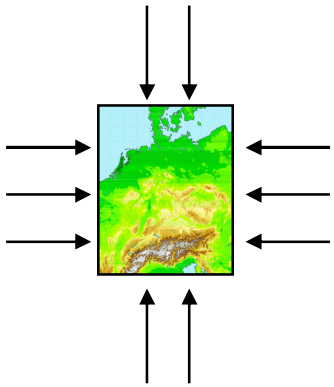
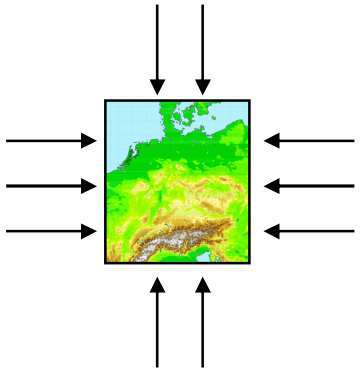


x

initial conditions boundary conditions model physics

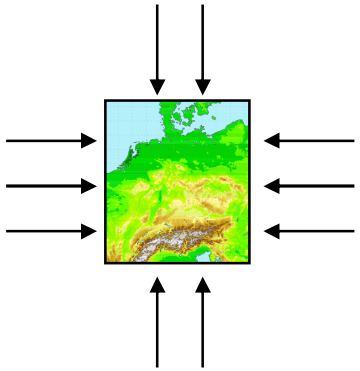
start with a simple approach

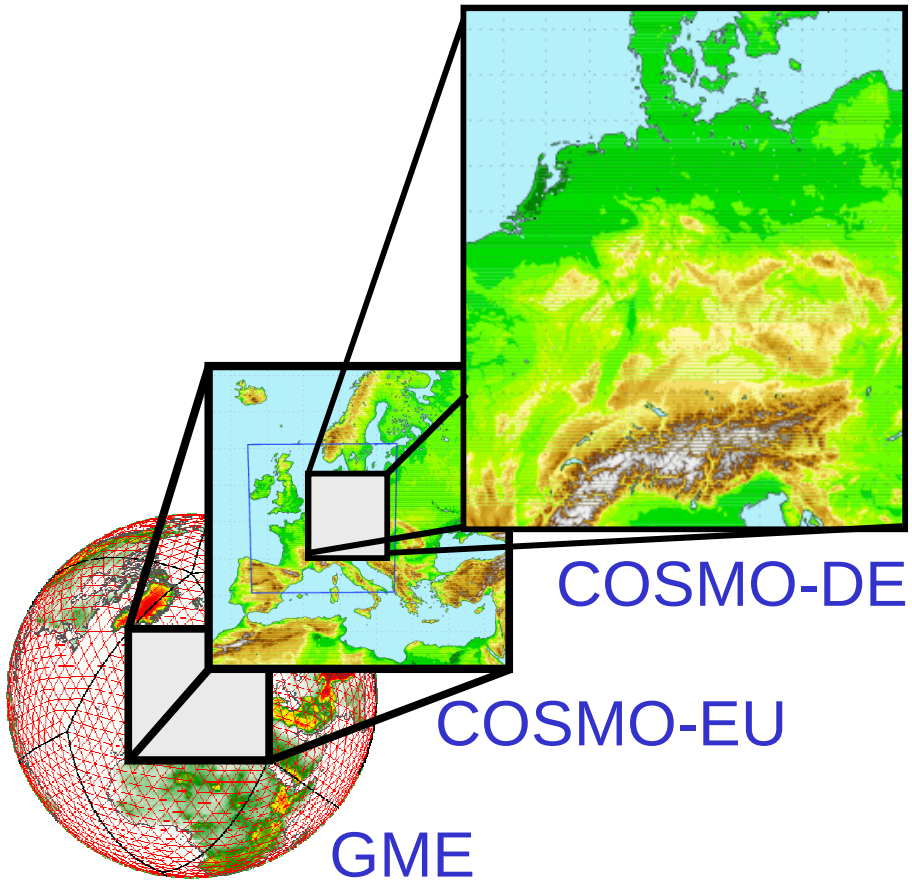
Perturbation of Boundary Conditions



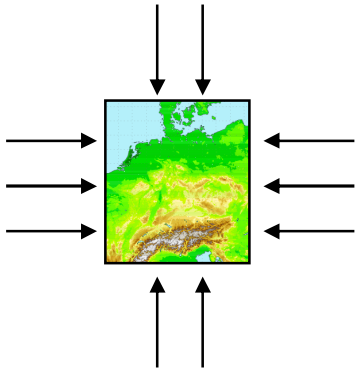
Perturbation of Boundary Conditions

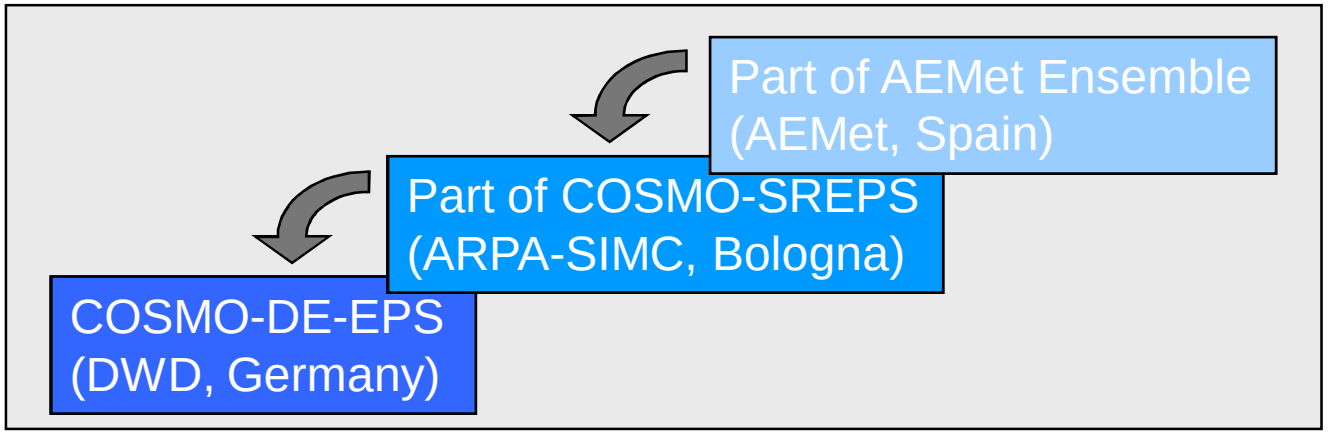
Reminder: operational chain





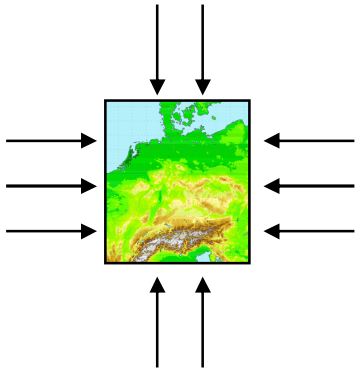
Perturbation of Boundary Conditions





(García-Moya et al., 2007)
(Marsigli et al., 2008)
(Gebhardt et al., 2009)

Perturbation of Boundary Conditions

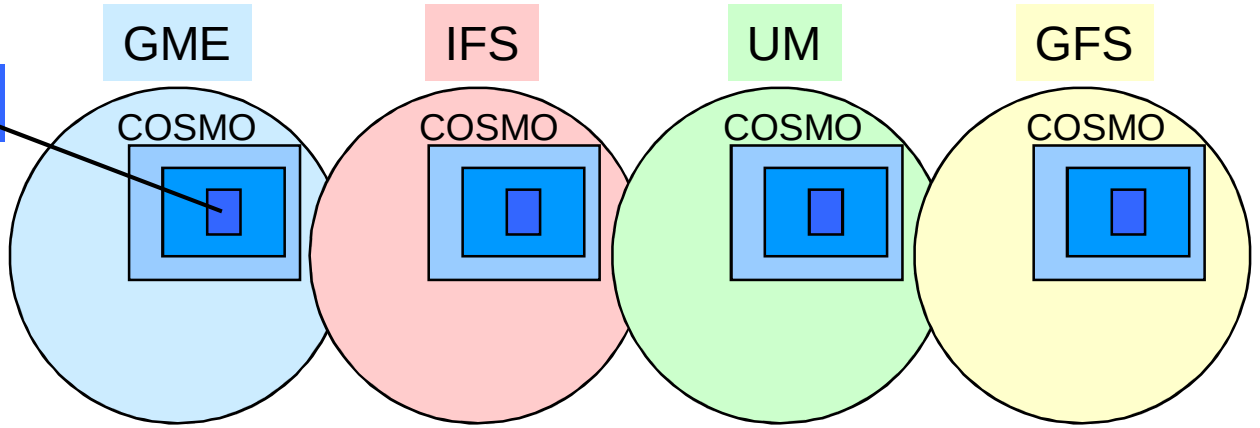


Part of AEMet Ensemble (AEMet, Spain)

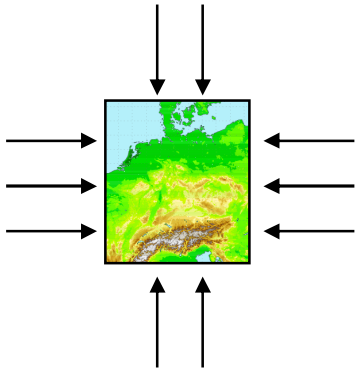
Part of COSMO-SREPS (ARPA-SIMC, Bologna)

COSMO-DE-EPS (DWD, Germany)

COSMO-DE (2,8km)



Perturbation of Boundary Conditions



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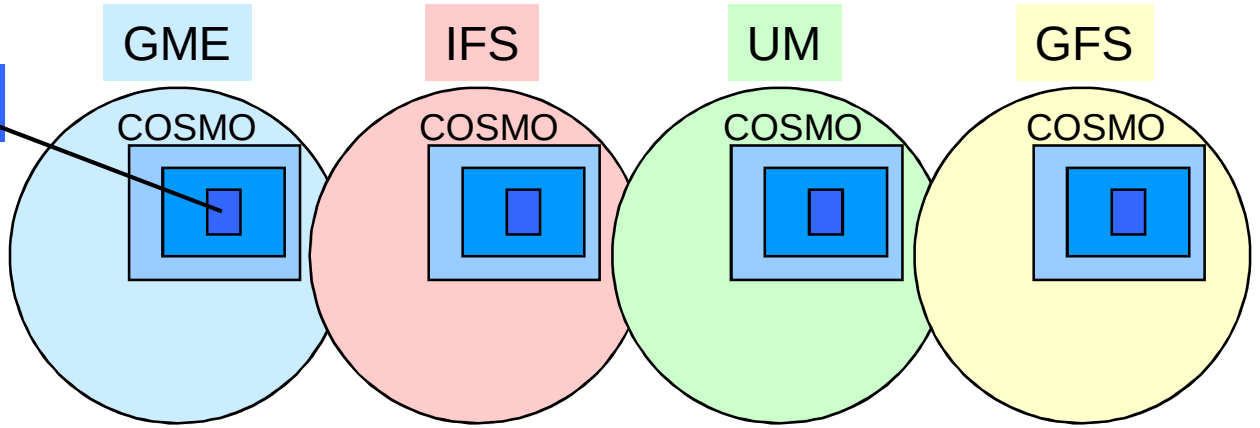
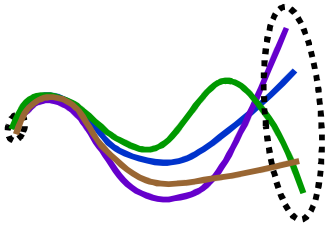
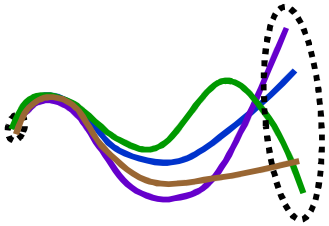


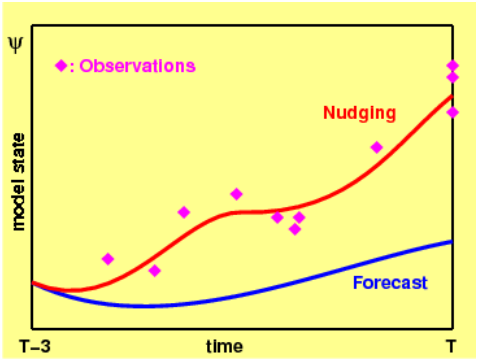
long-term Plan: take boundaries from ICON Ensemble

Perturbation of Initial Conditions



Perturbation of Initial Conditions





- **current work:**

  - perturb “nudging” at forecast start

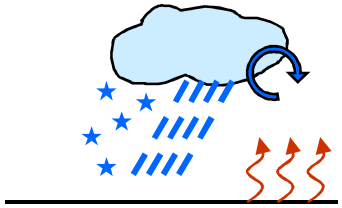
  - use differences between control and COSMO-SREPS

- **plans:**

  Ensemble Transform Kalman Filter (COSMO project KENDA)

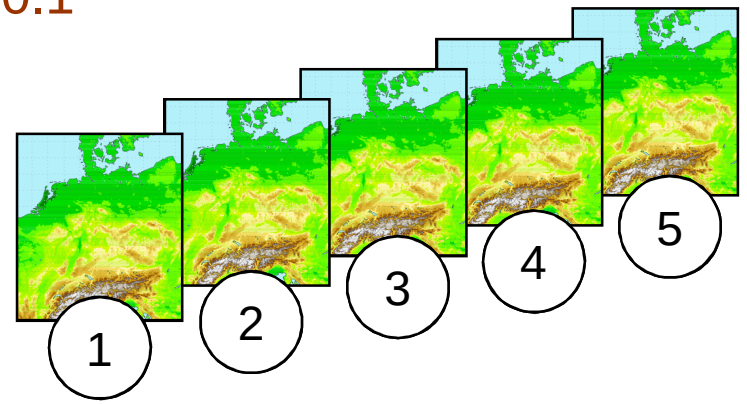
Perturbation of the Model

Perturbation of the Model



Alter parameters in physics parametrizations

1. entr_sc=0.0003 → entrain_sc=0.002
2. rlam_heat=1. → rlam_heat=10.
3. rlam_heat=1. → rlam_heat=0.1
4. …q_crit…
5. …tur_len…

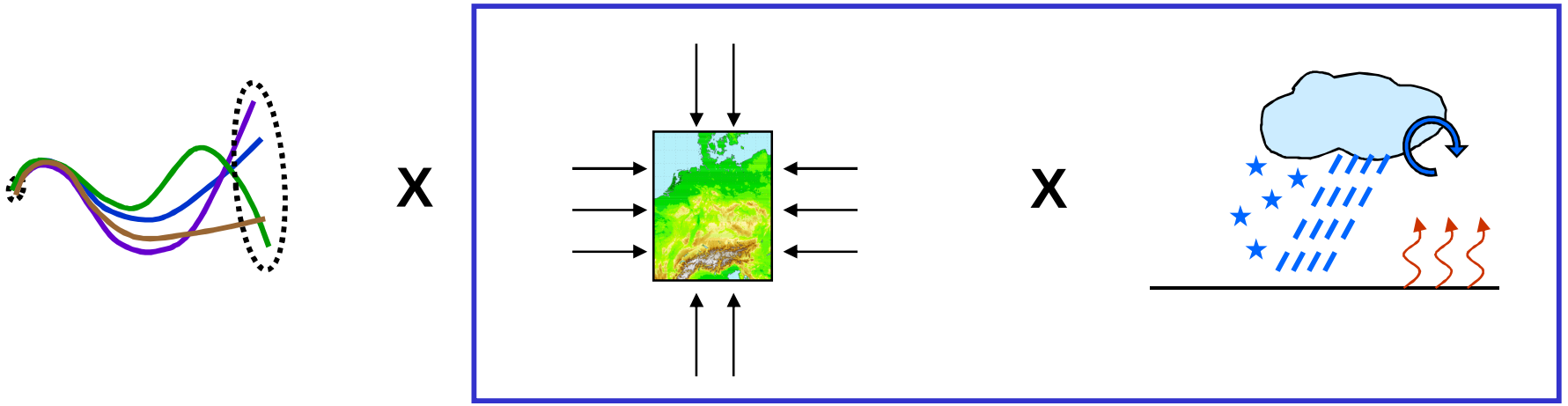


requires careful tuning → affect forecast, but not long-term quality

Current Experiments

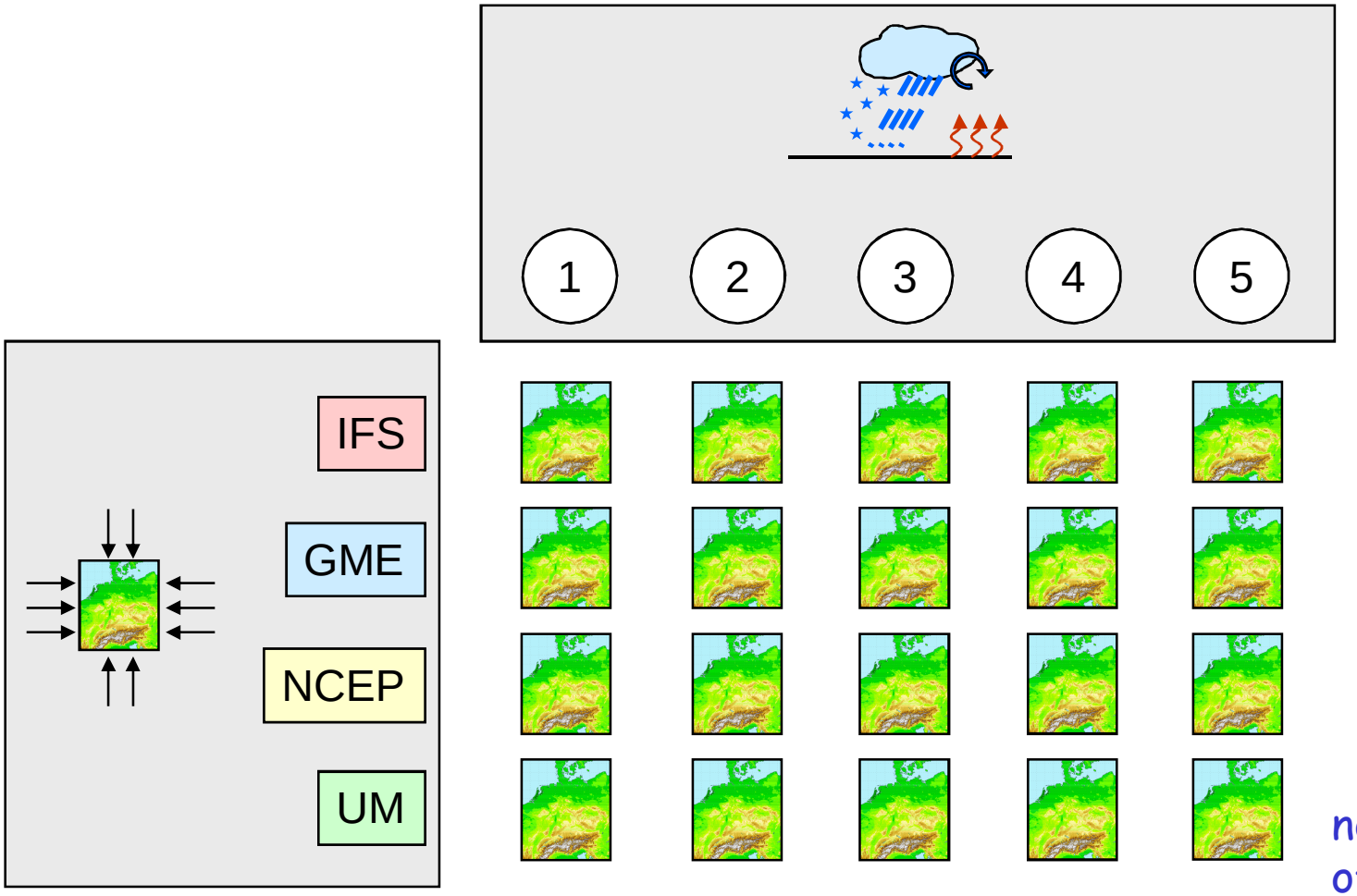
- experimental set-up
- examples

Current Status



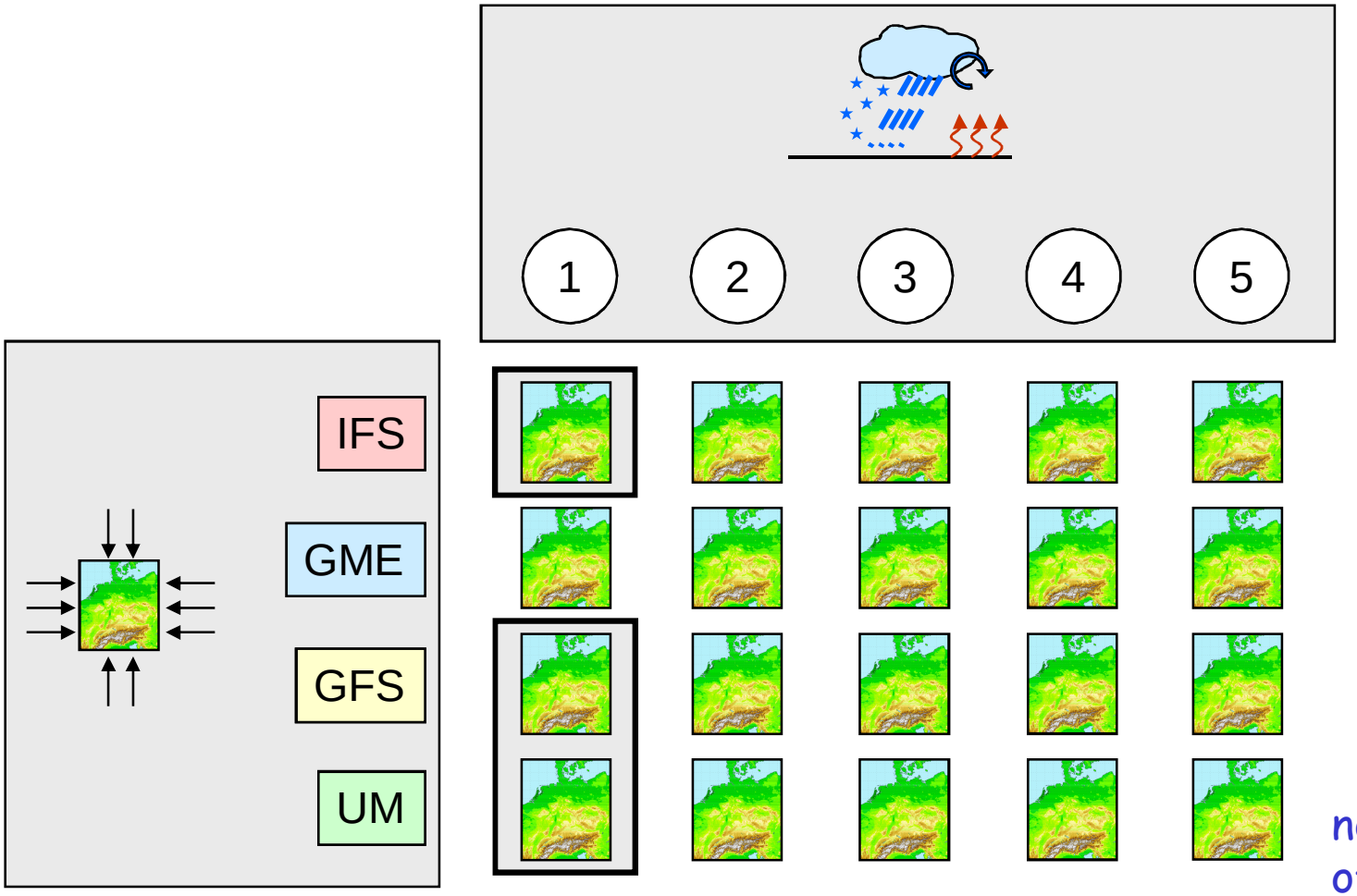
initial conditions x boundary conditions x model physics

Current Experiments



no perturbation
of initial conditions

Current Experiments



no perturbation
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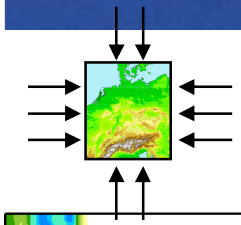
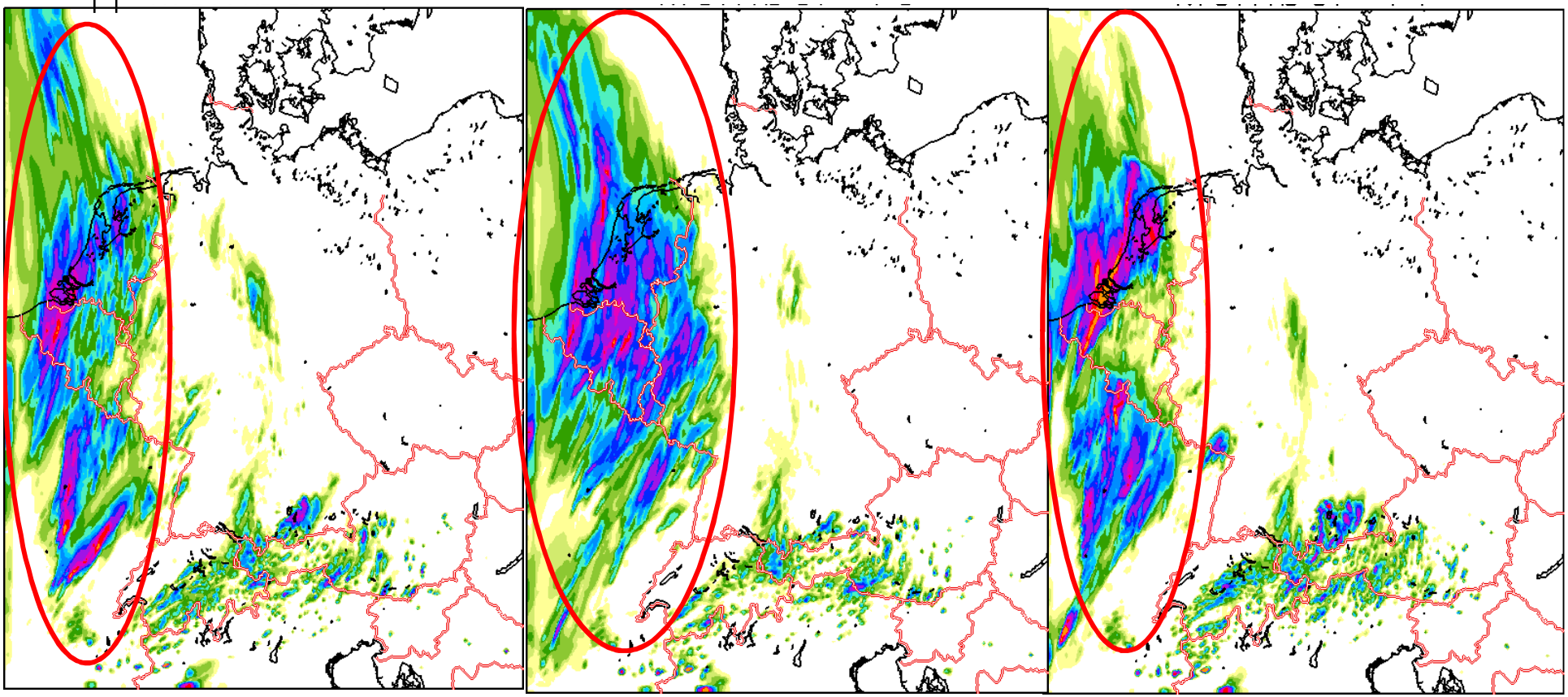
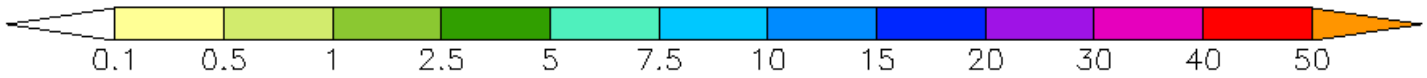
Deutscher Wetterdienst



2 July 2007, 00 UTC + 24h

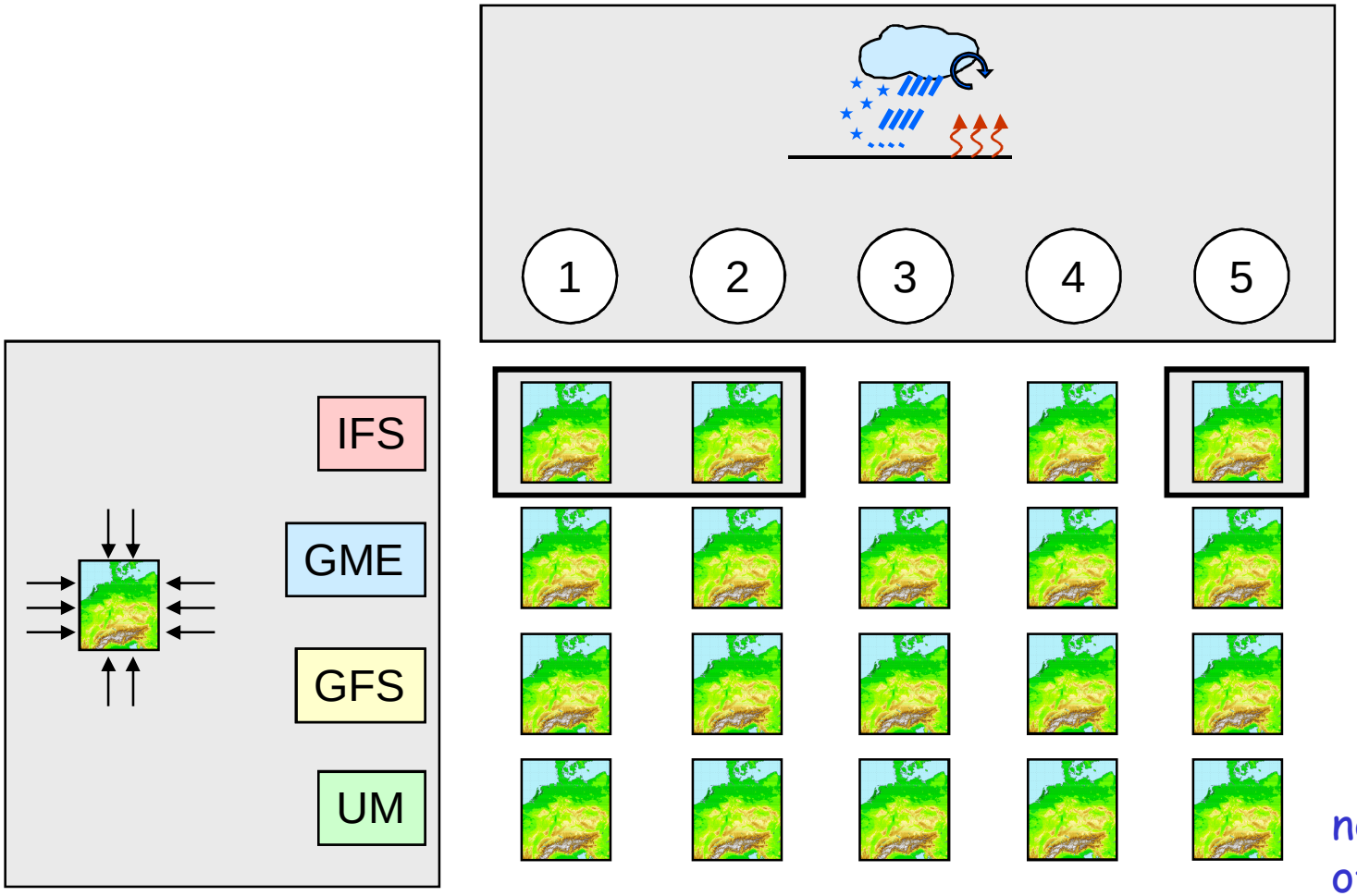
24h accumulations of precipitation [mm]





mm/24h

Current Experiments



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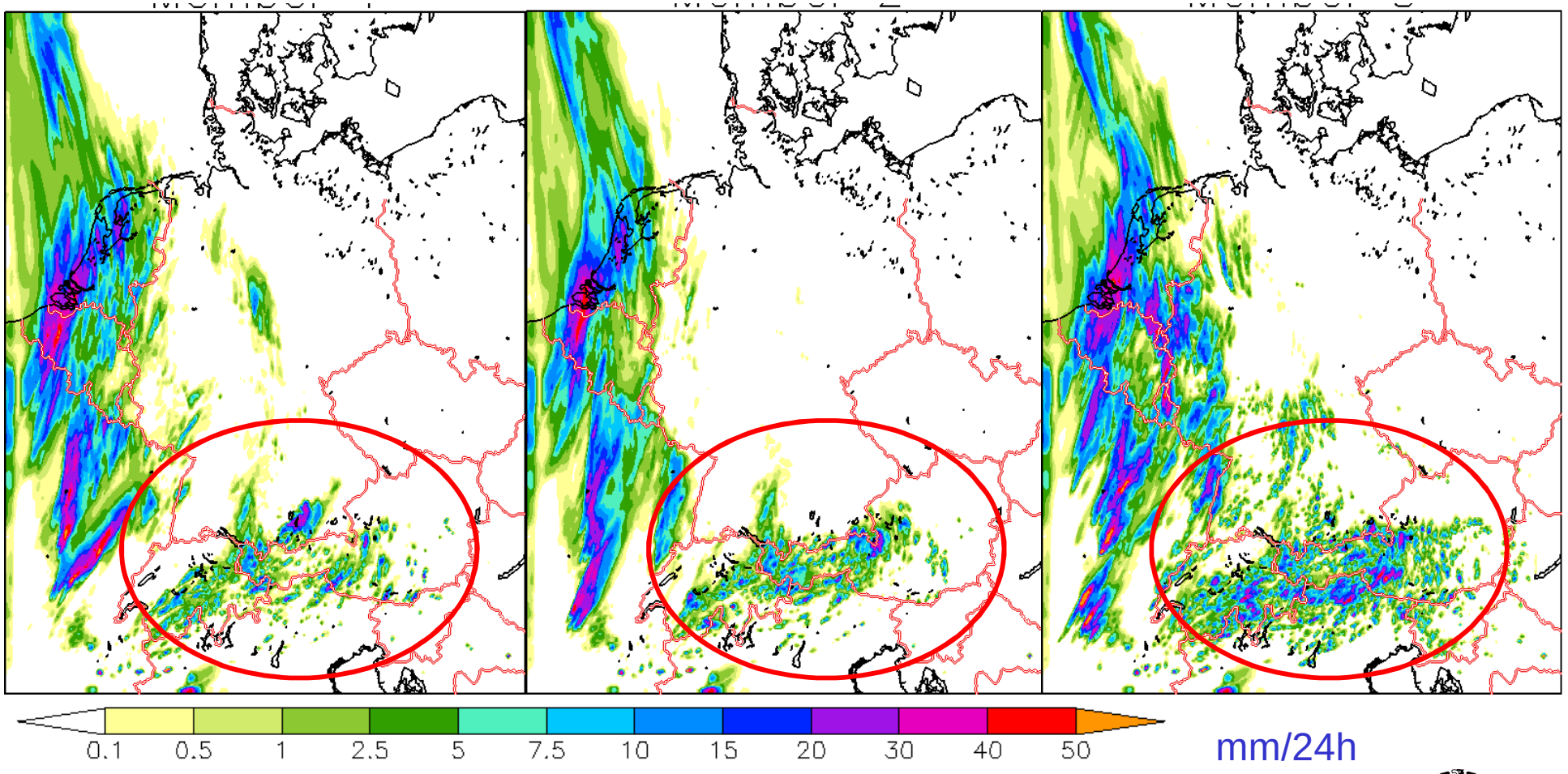
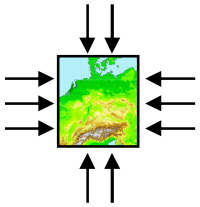


Ensemble Diagnostics

- how do perturbations affect the forecast?

Effect of perturbations on precipitation



boundaries:

dominate after a few hours

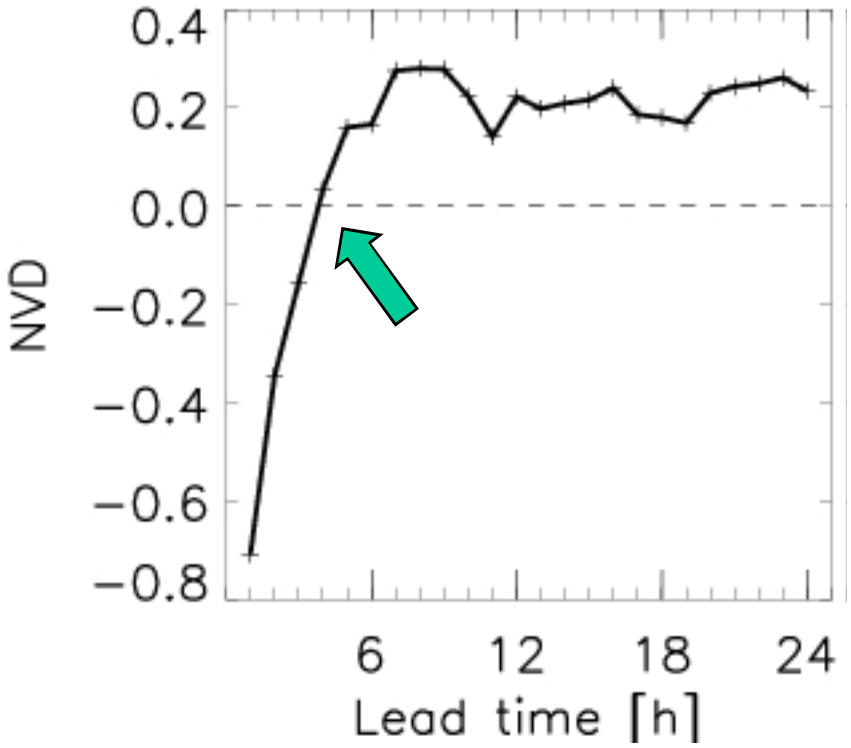
(not necessarily, also case-dependent)

physics:

dominate during first few hours

(Gebhardt et al., 2009)

Ensemble Dispersion (precipitation)



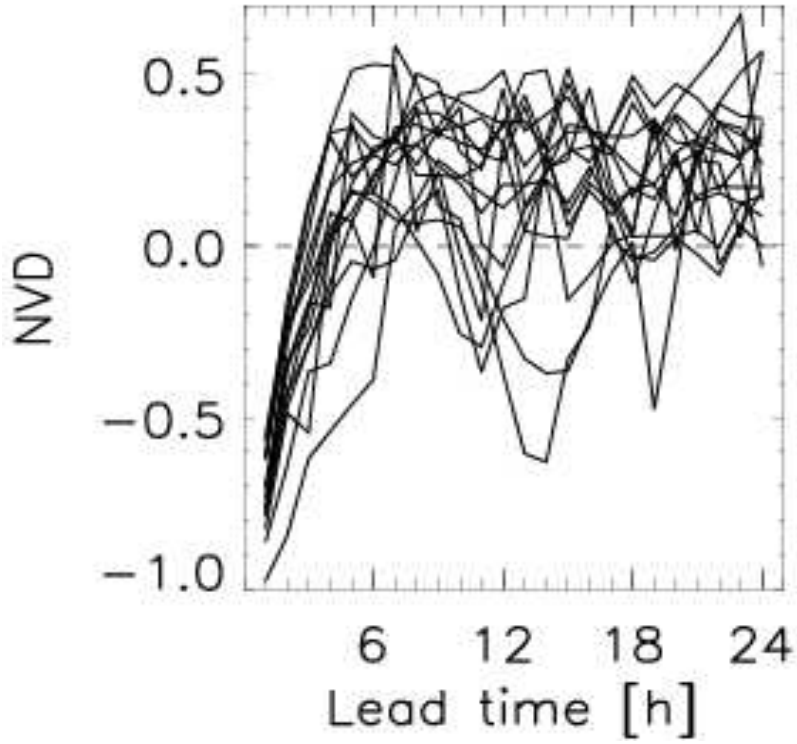
Normalized
Variance Difference

= variance (BC only)
- variance (PHY only)

normalized by
sum of variances

(Gebhardt et al., 2009)

Ensemble Dispersion (precipitation)



for individual days

Normalized
Variance Difference

= variance (BC only)
- variance (PHY only)

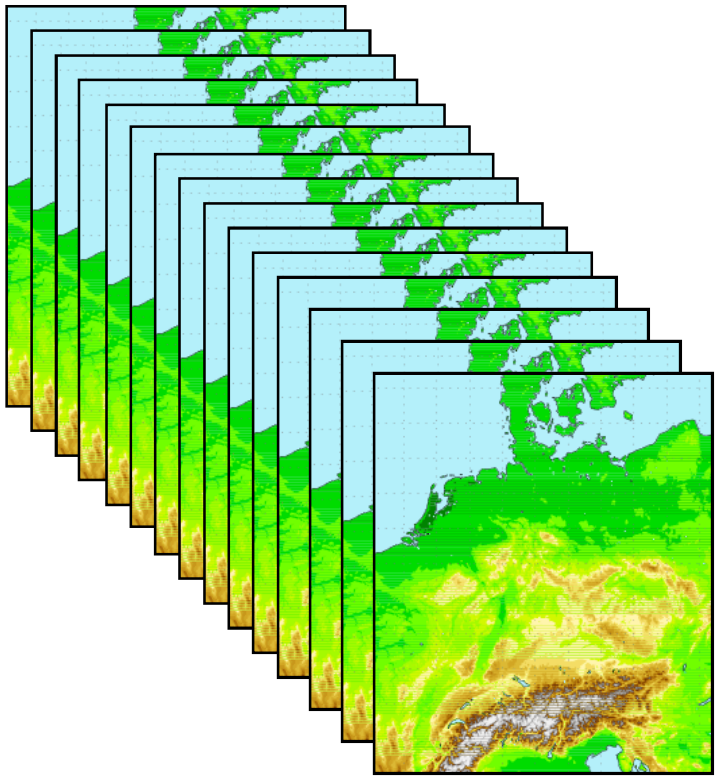
normalized by
sum of variances

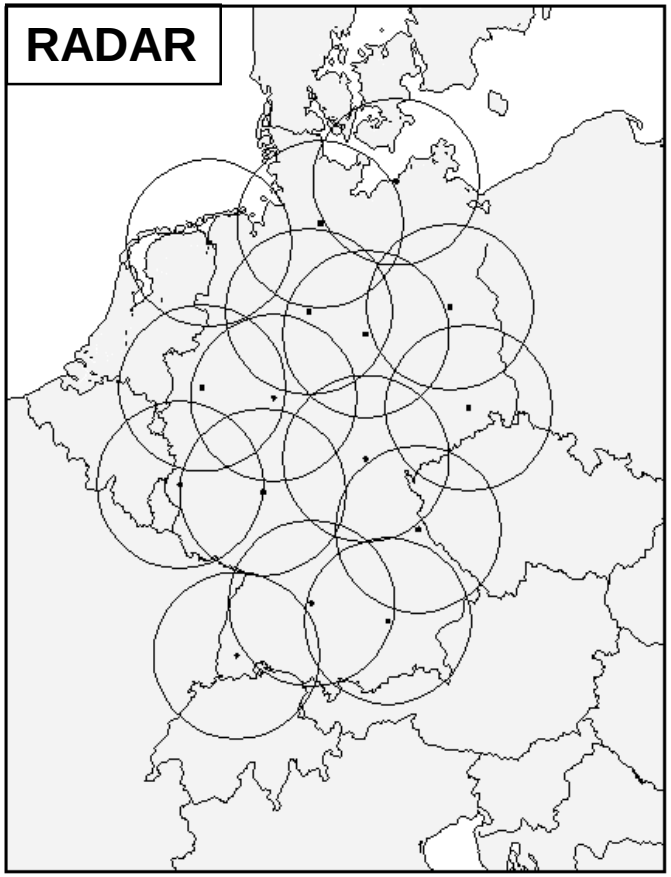
(Gebhardt et al., 2009)

Ensemble Verification

- how good is the Ensemble (at this stage)?

Verification Data Sets





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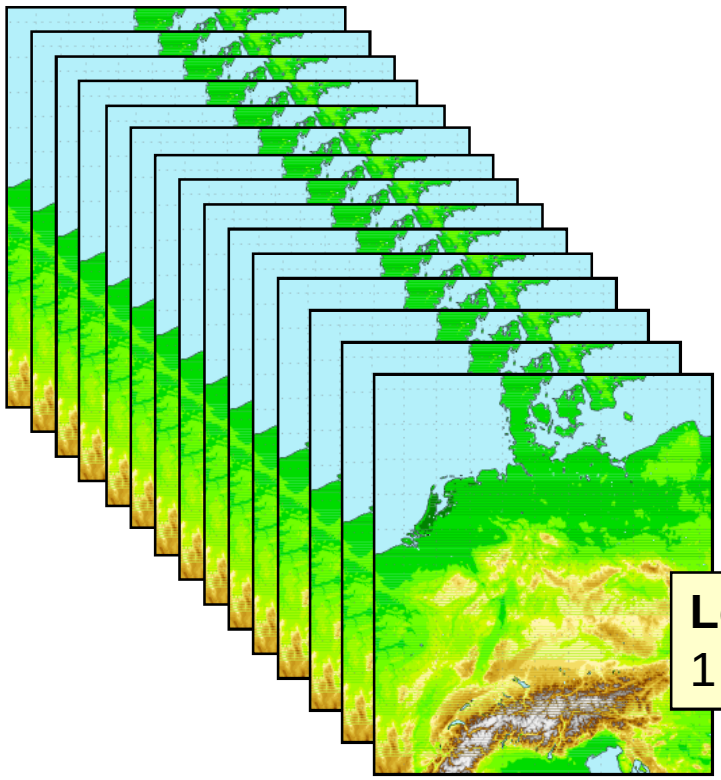
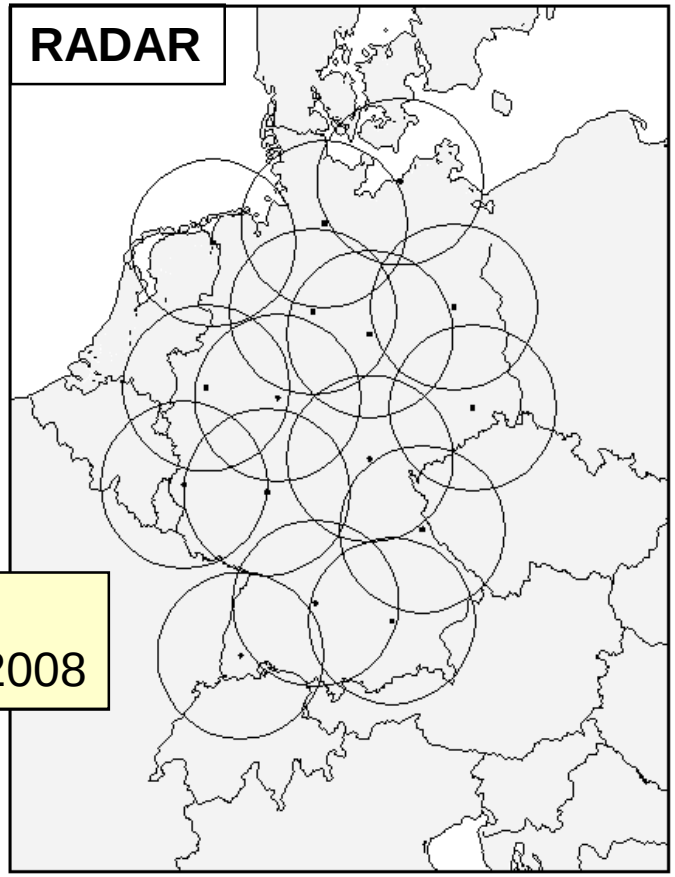




Longest Period:
1 July – 16 Sep 2008

Probabilistic Verification Measures

Traditional:

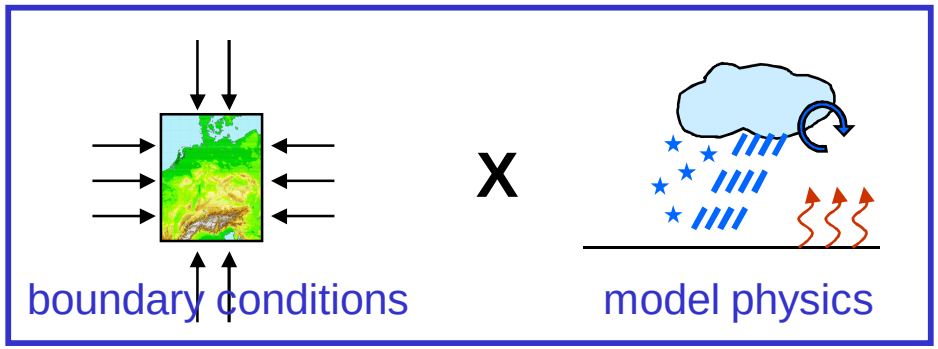
- Brier Score, Brier Skill Score
- ROC curve
- Reliability Diagram
- Talagrand Diagram
- Spread-Skill Relation

with focus on precipitation, also scale-dependent

Verification Results

Verification Results

current setup

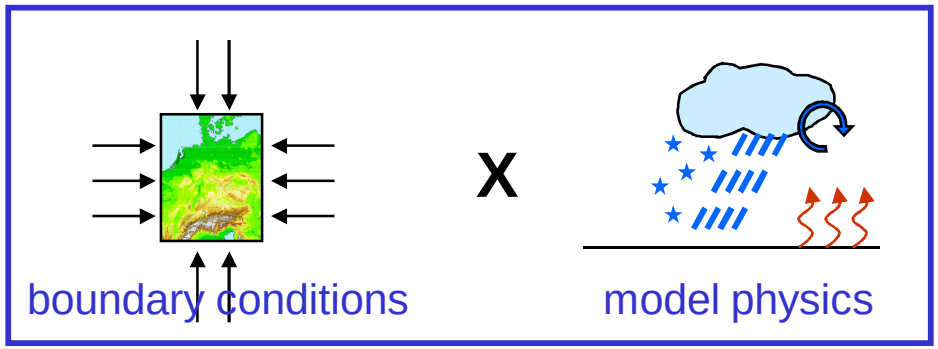


without
- initial condition perturbations
- postprocessing

!

Verification Results

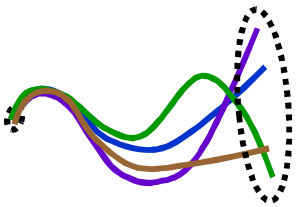
current setup



without
- initial condition perturbations
- postprocessing

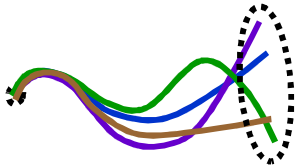
!

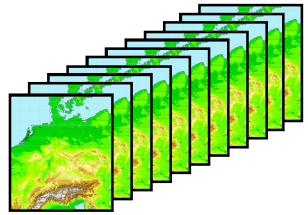
- ensemble is superior to single simulation
- ensemble is underdispersive



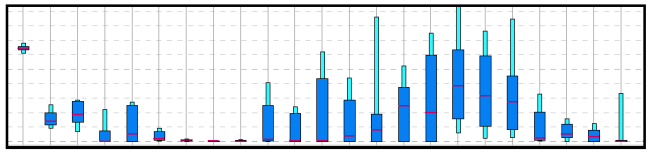
As a Reminder: Tasks within Project

- implementation of perturbations





- verification & diagnostics
- post-processing
- visualization
- early user feedback



Early User Feedback

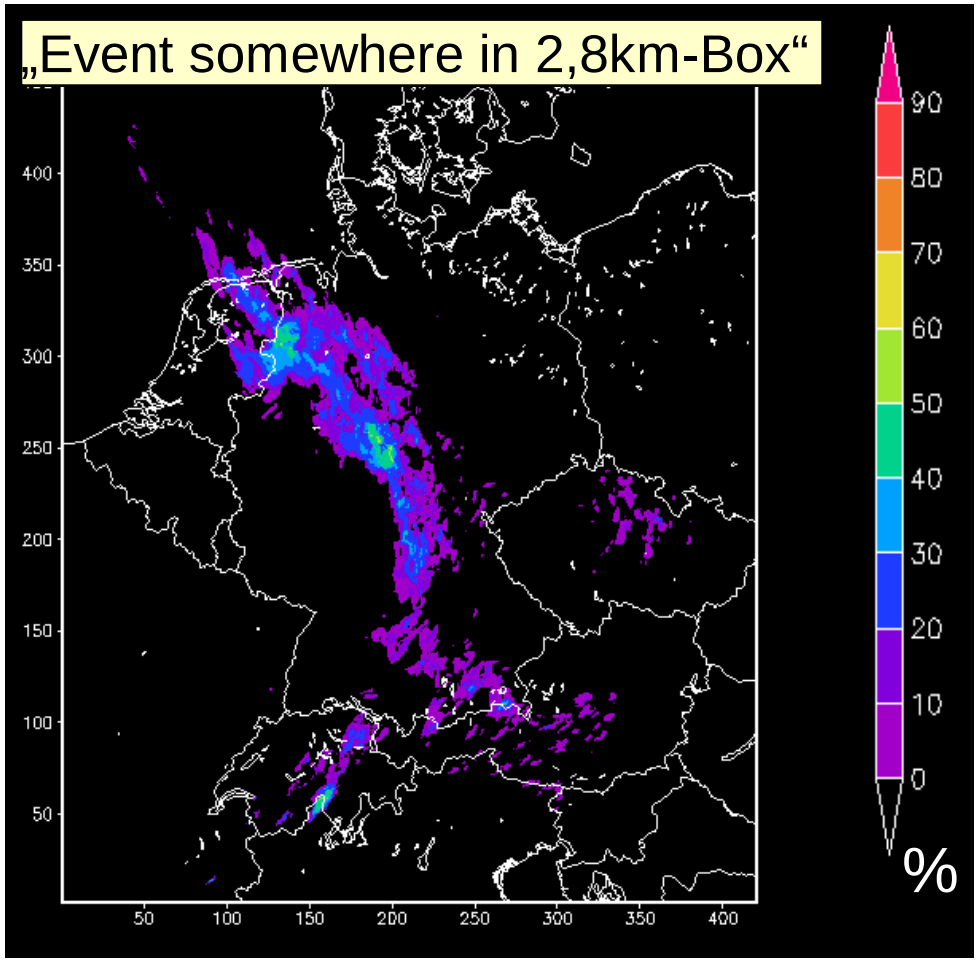
- work towards acceptance

- work towards useful interpretation

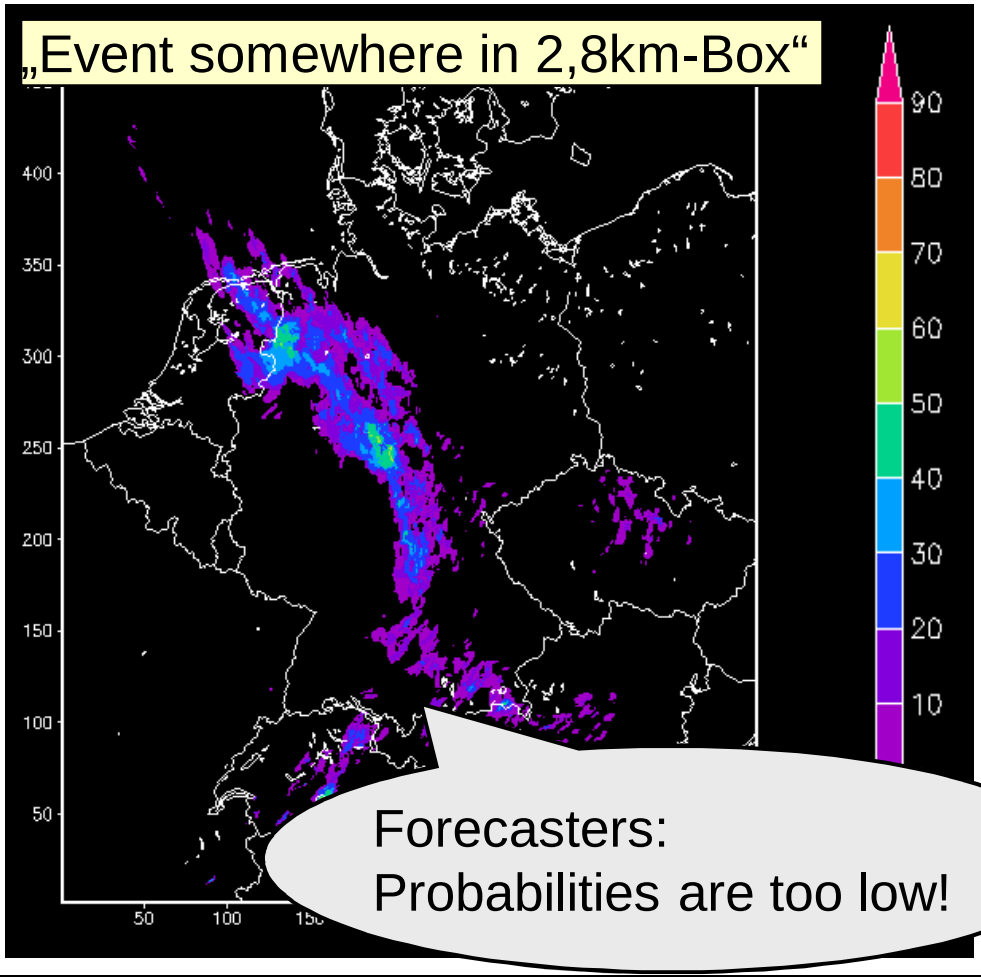
Early User Feedback

- Forecasters (DWD)

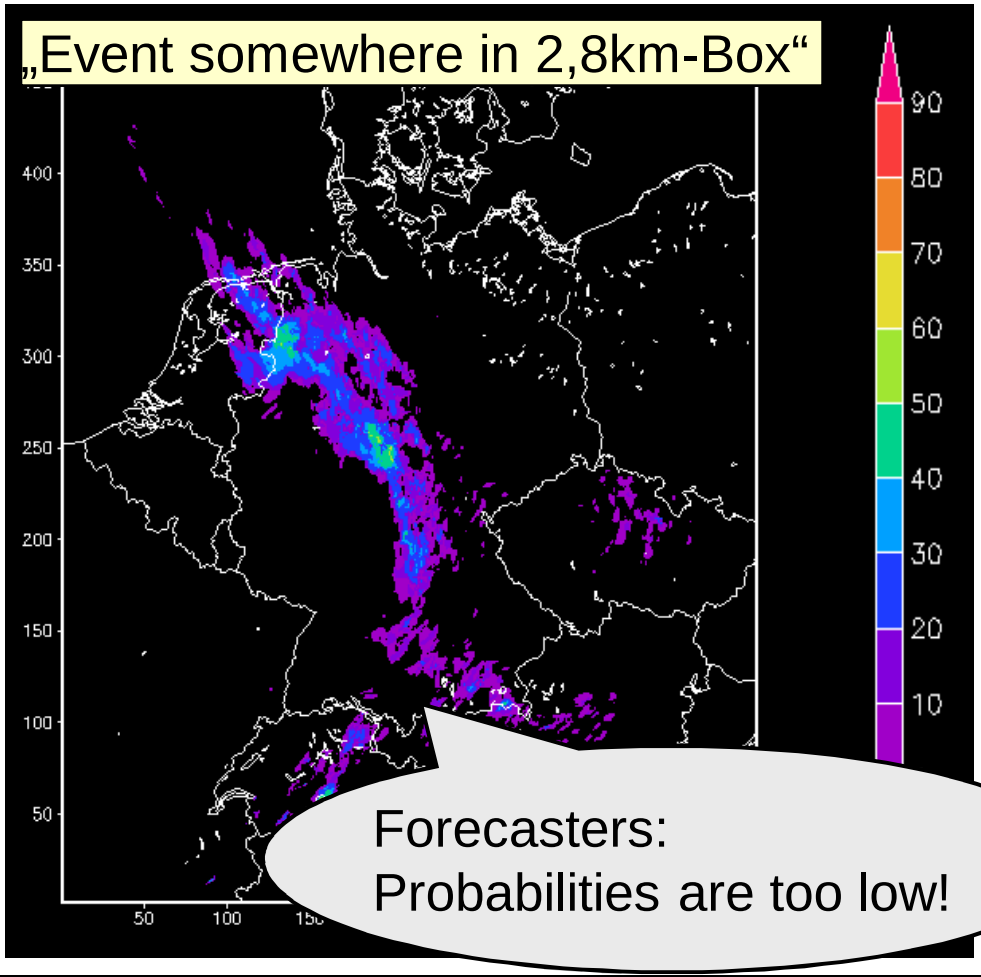
EPS Product Example: Probability Maps



EPS Product Example: Probability Maps



EPS Product Example: Probability Maps



Forecasters:
Probabilities are too low!

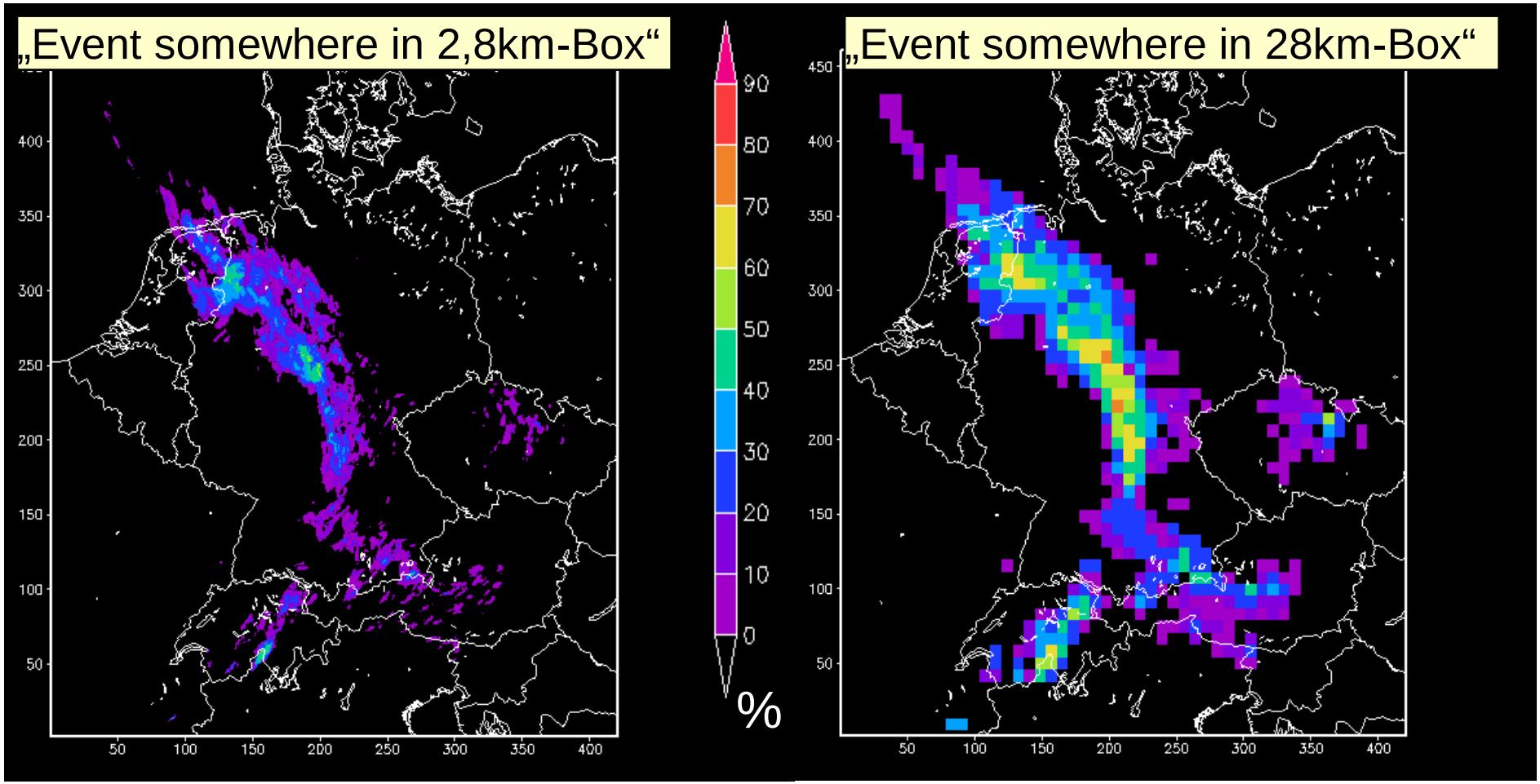
Reason:

Forecasters are used to larger reference regions

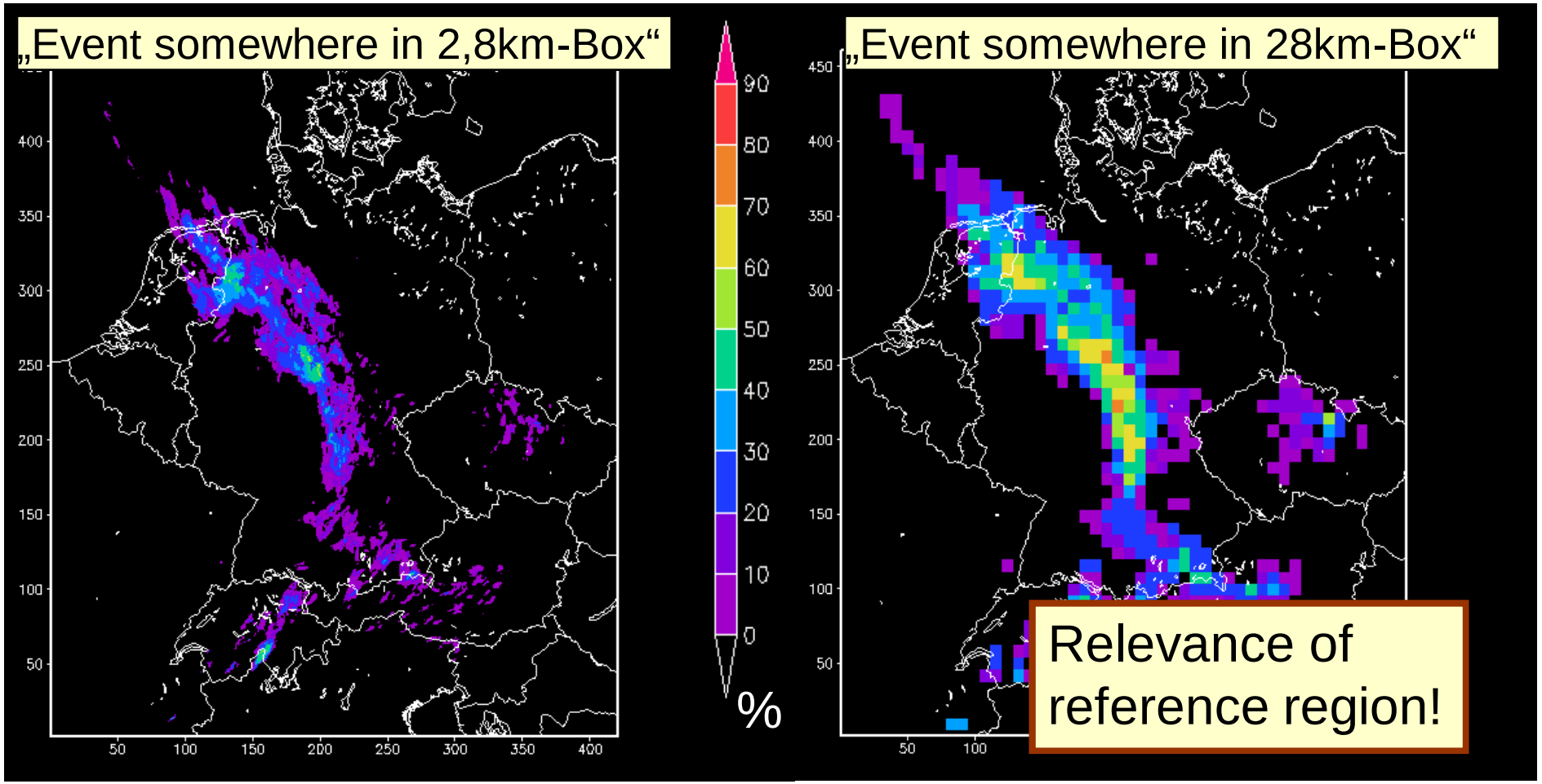
→ Experiment:

present probabilities on coarser grid

EPS Product Example: Probability Maps



EPS Product Example: Probability Maps



Literature about perception of ensemble forecasts:

Demeritt, D., Cloke, H., Pappenberger, F., Thielen, J., Bartholmes, J. and M.-H. Ramos (2007): Ensemble predictions and perceptions of risk, uncertainty, and error in flood forecasting. Environmental Hazards 7, 115-127.

Gigerenzer, G., Hertwig, R., van den Broek, E., Fasolo, B. and K.V.Katsikopoulos (2005): „A 30% Chance of Rain Tomorrow“: How does the public understand probabilistic weather forecasts? Risk Analysis 25(3), 623-629.

Joslyn, S., Pak, K., Jones, D., Pyles, J. and E. Hunt (2007): The effect of probabilistic information on threshold forecasts. Weather and Forecasting 22, 804-812.

Morss, R.E., Demuth, J.L. and J.K. Lazo (2008): Communicating Uncertainty in Weather Forecasts: A Survey of the U.S. Public. Weather and Forecasting 23, 974-991.

Morss, R.E., Wilhelmi, V.W., Downton, M.W. and E. Gruntfest (2005): Flood risk, uncertainty, and scientific information for decision making: Lessons from an interdisciplinary project. Bulletin of the American Meteorological Society 86(11), 1593-1601.

National Research Council (2006): Completing the Forecast: Characterizing and Communicating Uncertaintiy for Better Decisions Using Weather and Climate Forecasts. National Academies Press, 124 pp.

Nobert, S., Demeritt, D. and H. Cloke (2009): Using Ensemble Predictions for Operational Flood Forecasting: Lessons from Sweden. Submitted to Journal of Flood Risk Management.

Roulston, M.S., Bolton, G.E., Kleit, A.N. and A.L. Sears-Collins (2006): A laboratory study of the benefits of including uncertainty information in weather forecasts. Weather and Forecasting 21, 116-122.

Back to the Project COSMO-DE-EPS:

Summary and Challenges

Summary of Project COSMO-DE-EPS

- setting up a convection-permitting ensemble
- with prospect of becoming operational
- dealing with all parts of forecast chain
  (perturbations, products, postprocessing, verification, users)
- simple approach first, then keep improving

Challenges of Project COSMO-DE-EPS

- scientific representation of uncertainties

  e.g. getting appropriate spread

- technical implementation

  e.g. amount of data

- communication to the user

  e.g. appropriate spatial scale

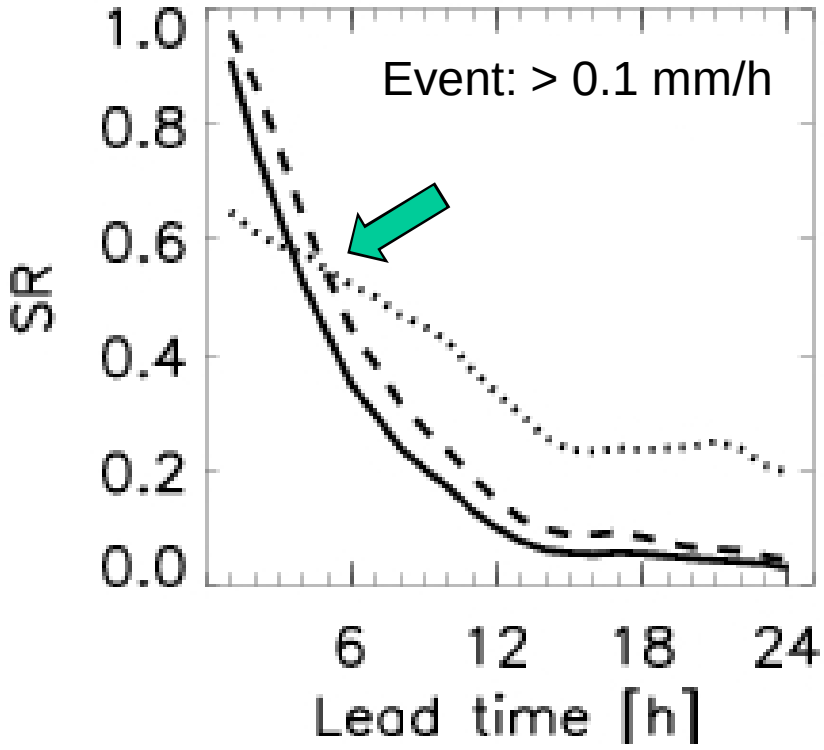
Thank You

For Your Attention

Extra Slides

More Diagnostics & Verification

Ensemble Dispersion (precipitation)



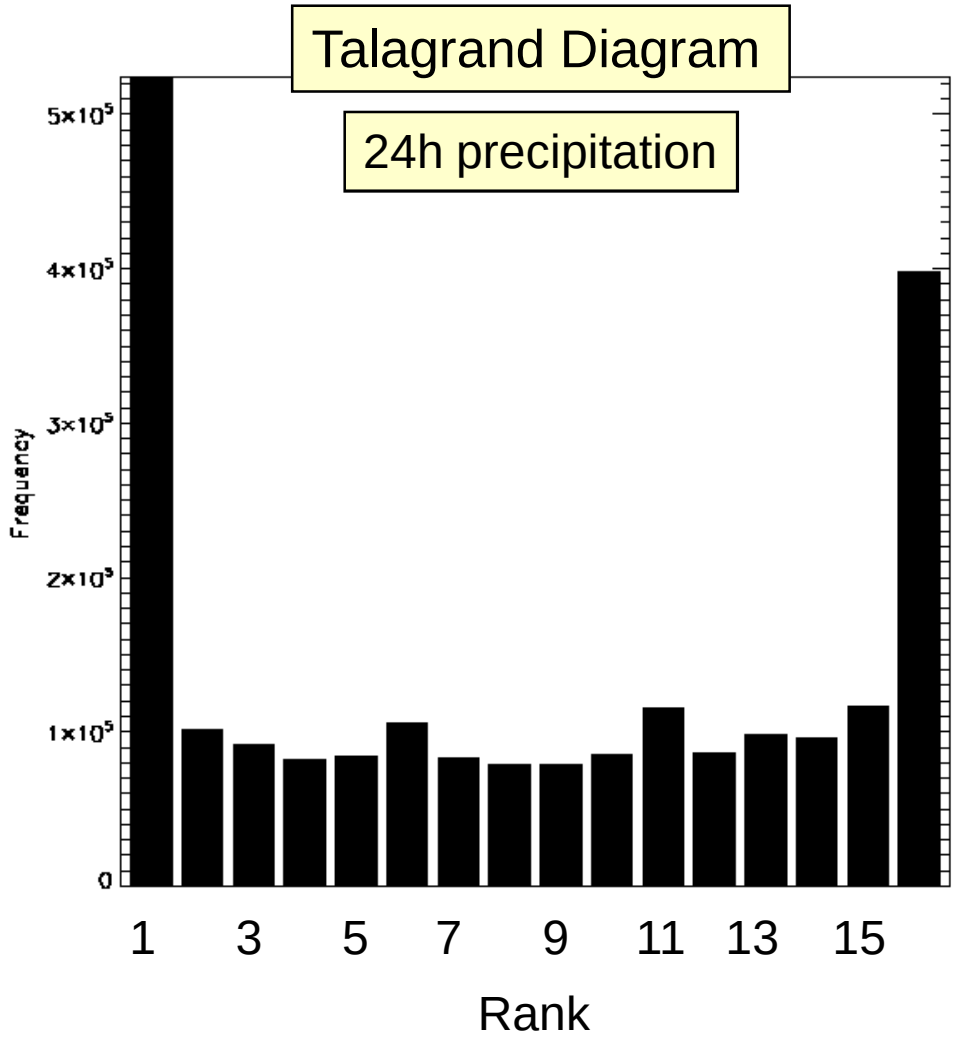
Spread Ratio

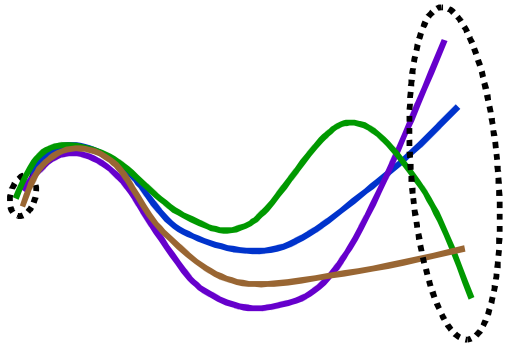
$$= \frac{\#(GP_{all\ members})}{\#(GP_{at\ least\ 1\ member})}$$

⇐ physics only

⇐ boundary conditions only

(Gebhardt et al., 2009)





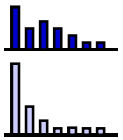
observation

Example of Verification

Example of Verification

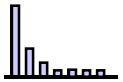
Frequencies of precipitation amount

- for ensemble forecasts (members)
- for observations



Example of Verification

Frequencies of precipitation amount

- for ensemble forecasts (members) 
- for observations 

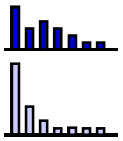
Conditional on Categories of Ensemble Mean Forecast:

Ens.Mean:	Ens.Mean:	Ens.Mean:
no & low precip	slight precip	medium & heavy precip

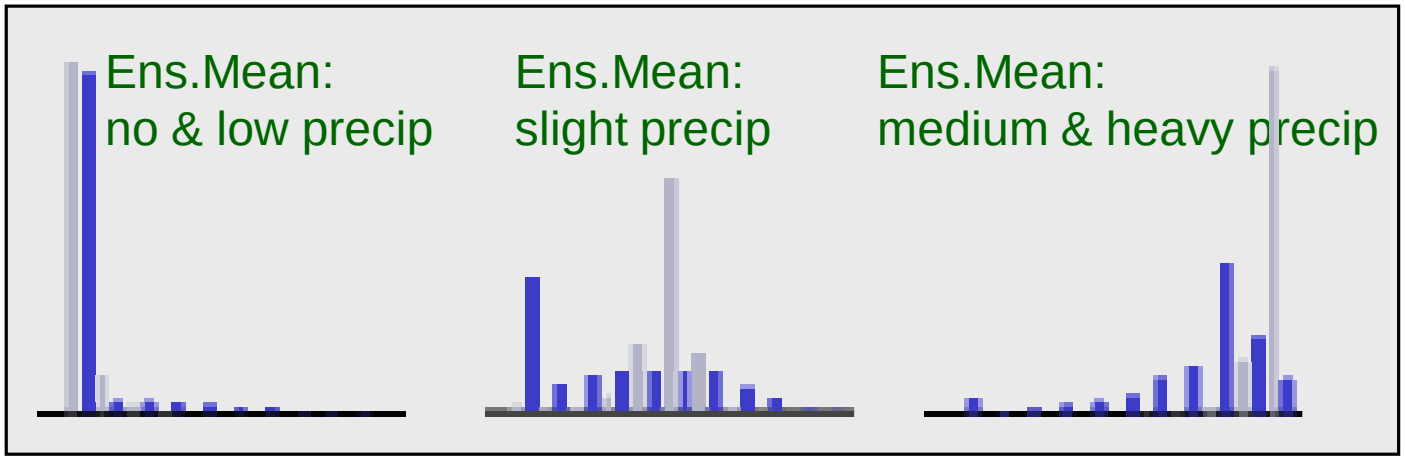
Example of Verification

Frequencies of precipitation amount

- for ensemble forecasts (members)
- for observations



Conditional on Categories of Ensemble Mean Forecast:

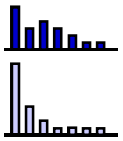


Lead time:
0 - 6 hours

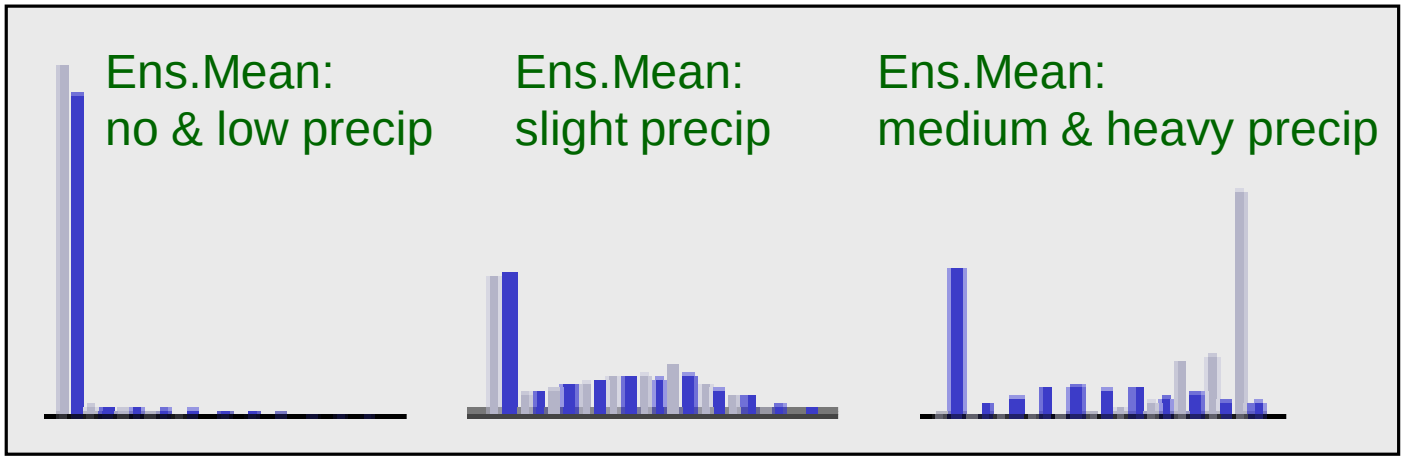
Example of Verification

Frequencies of precipitation amount

- for ensemble forecasts (members)
- for observations



Conditional on Categories of Ensemble Mean Forecast:

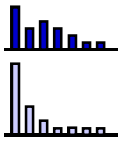


Lead time:
18 - 24 hours

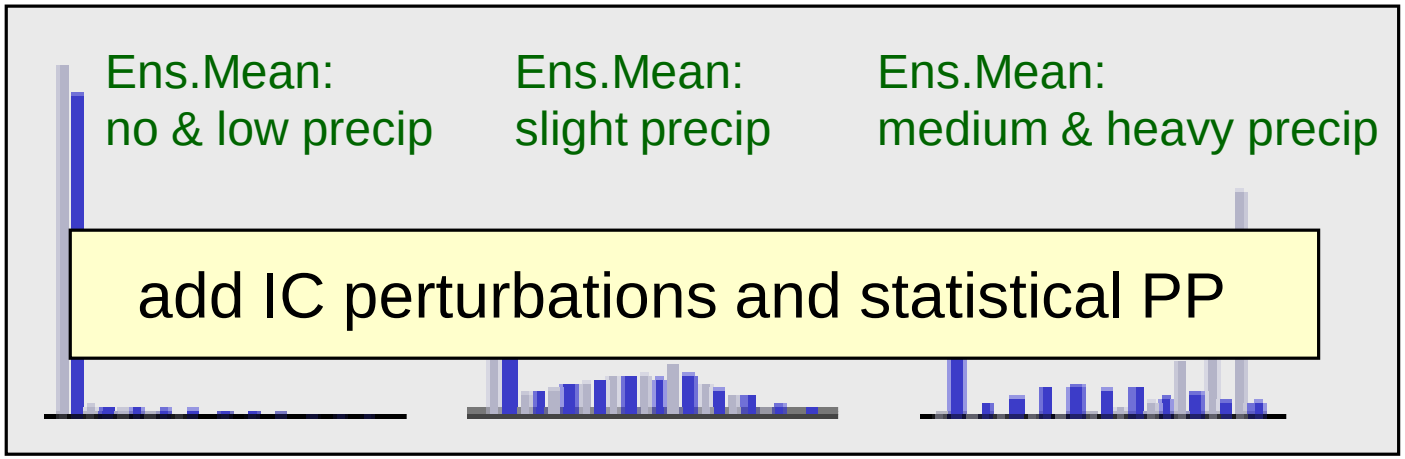
Example of Verification

Frequencies of precipitation amount

- for ensemble forecasts (members)
- for observations

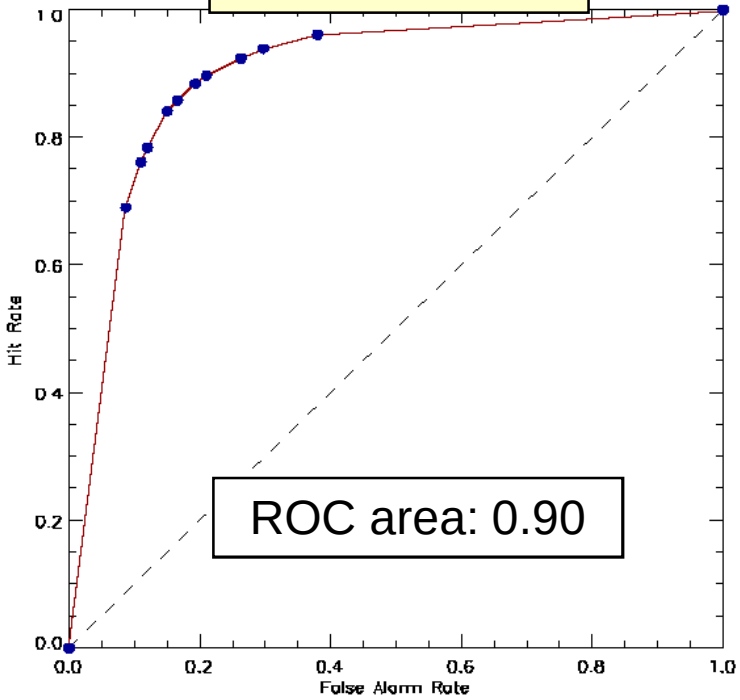


Conditional on Categories of Ensemble Mean Forecast:



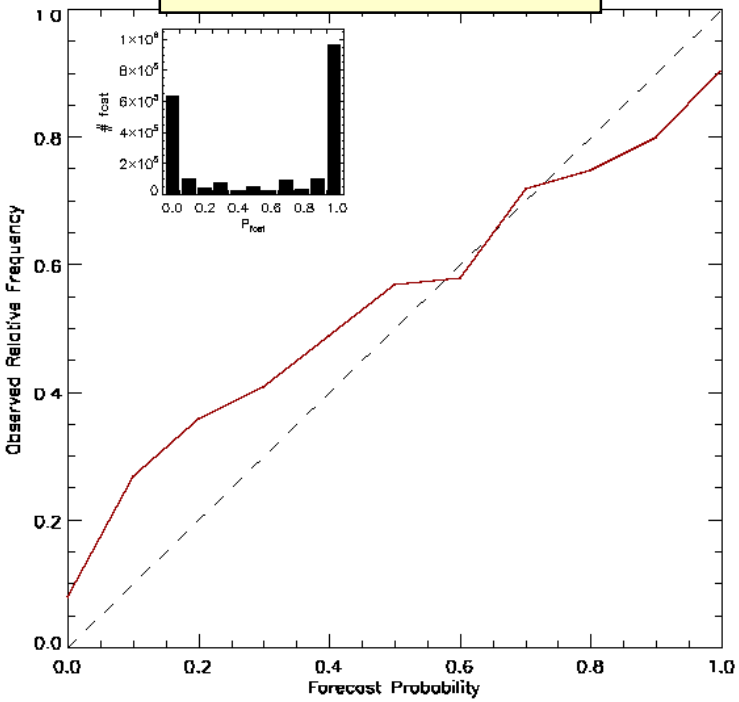
Lead time:
18 - 24 hours

ROC Curve



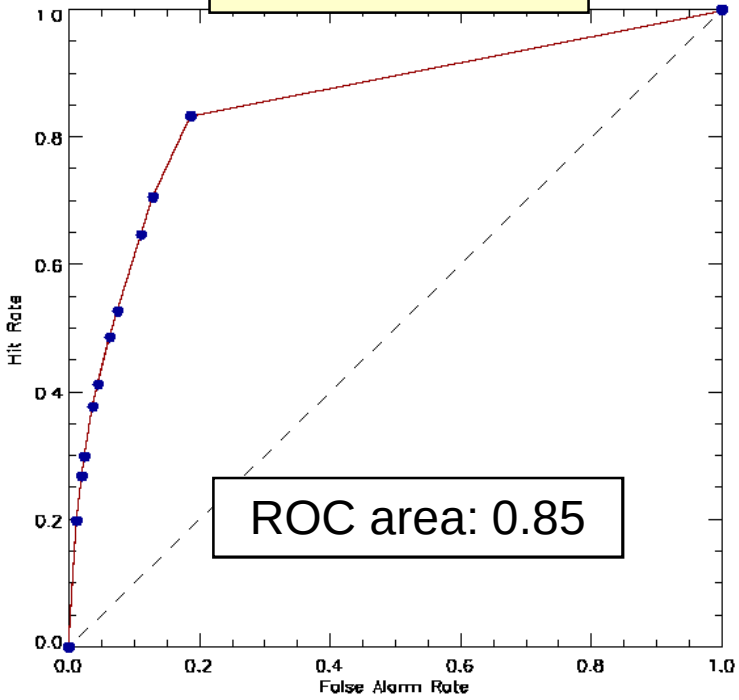
ROC area: 0.90

Reliability Diagram



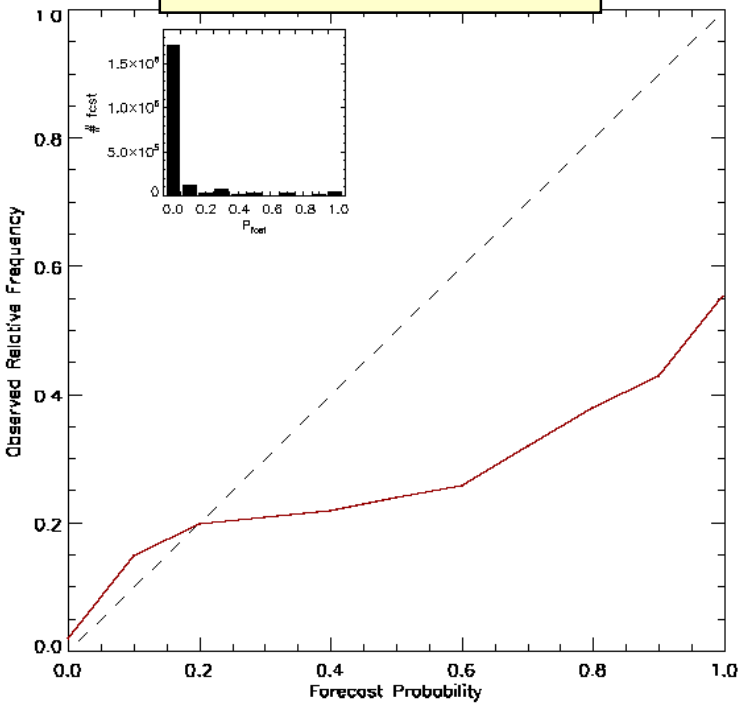
Threshold: 0.1mm/24h

ROC Curve



ROC area: 0.85

Reliability Diagram

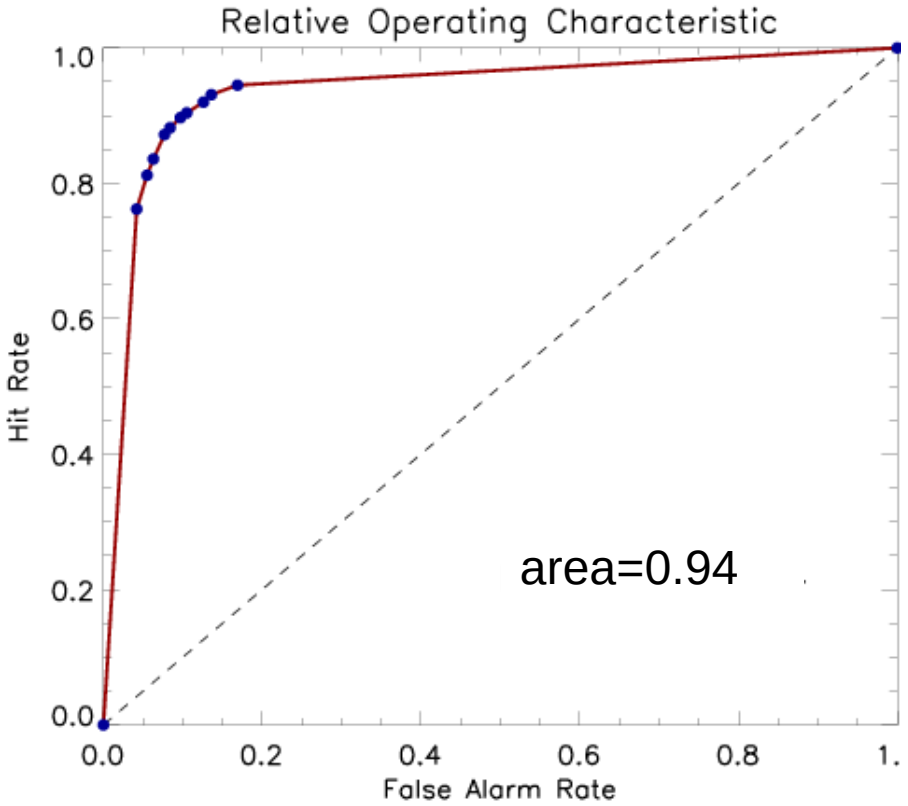


Threshold: 10mm/24h

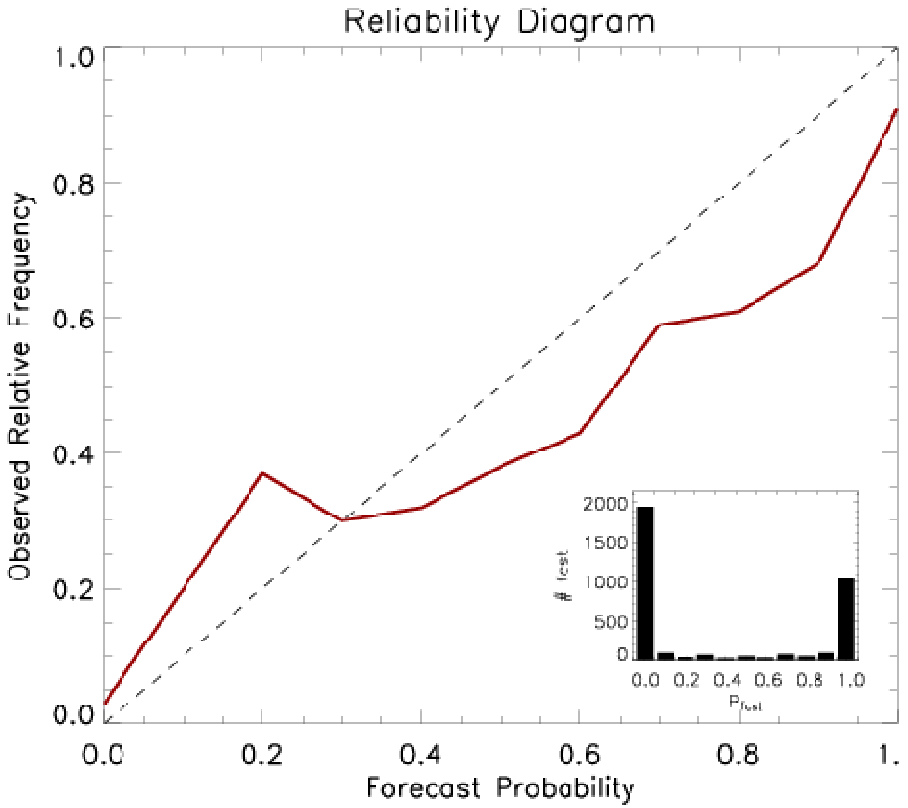
Verification results for 2m-temperature 12UTC

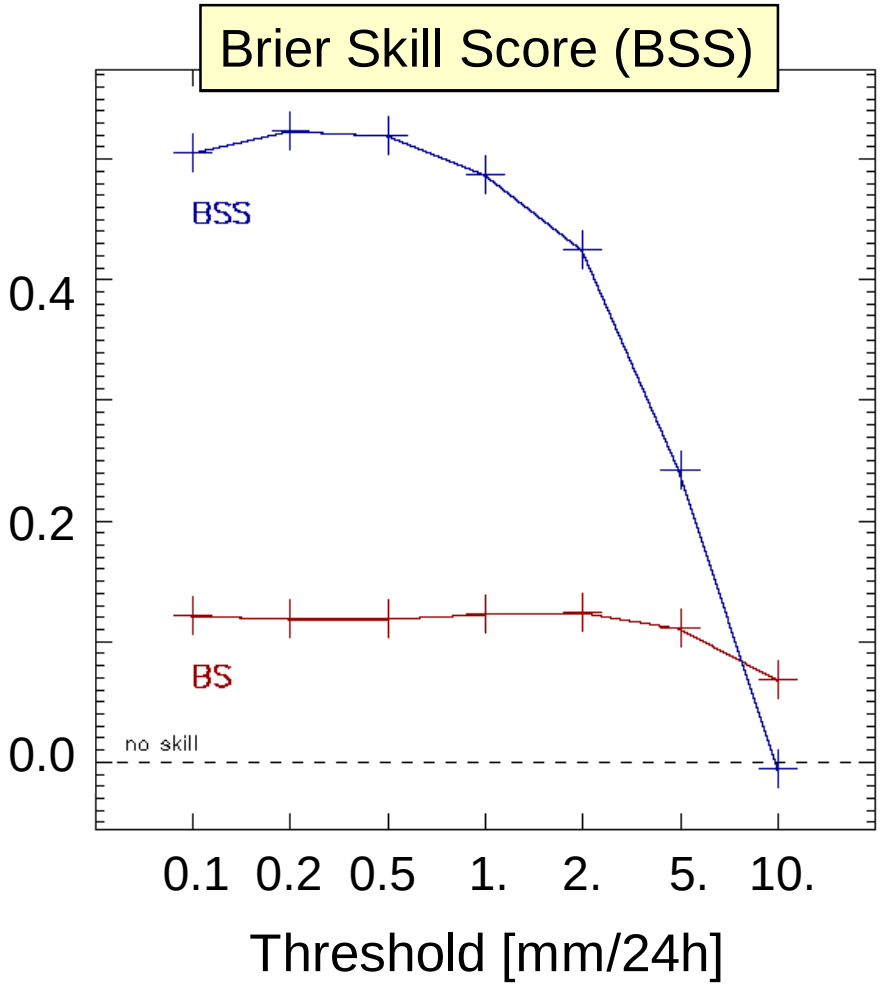
threshold: 25℃

ROC



Reliability

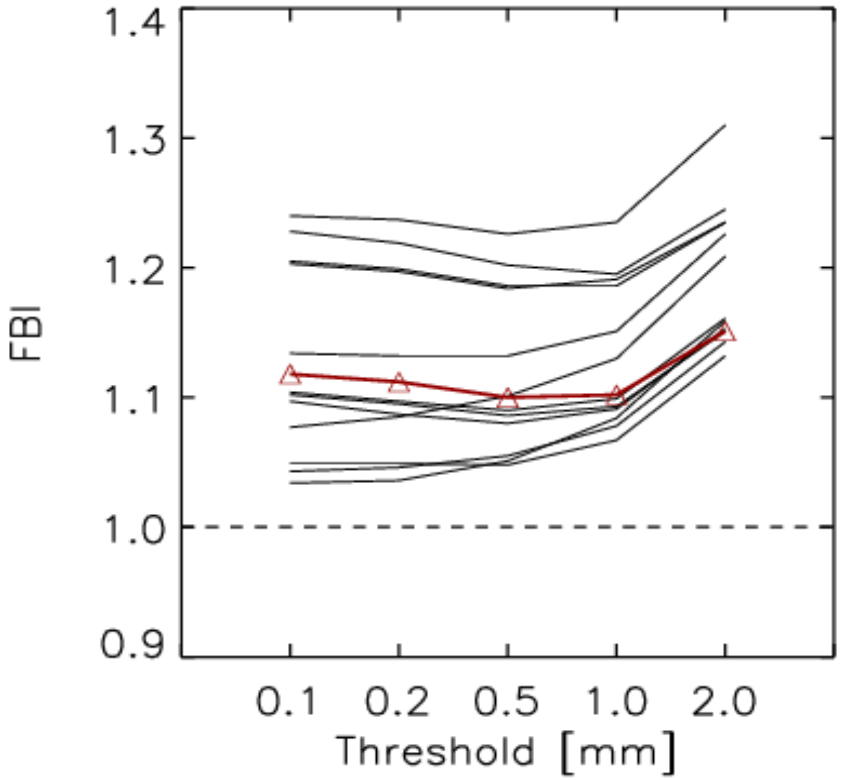




24 hour precipitation

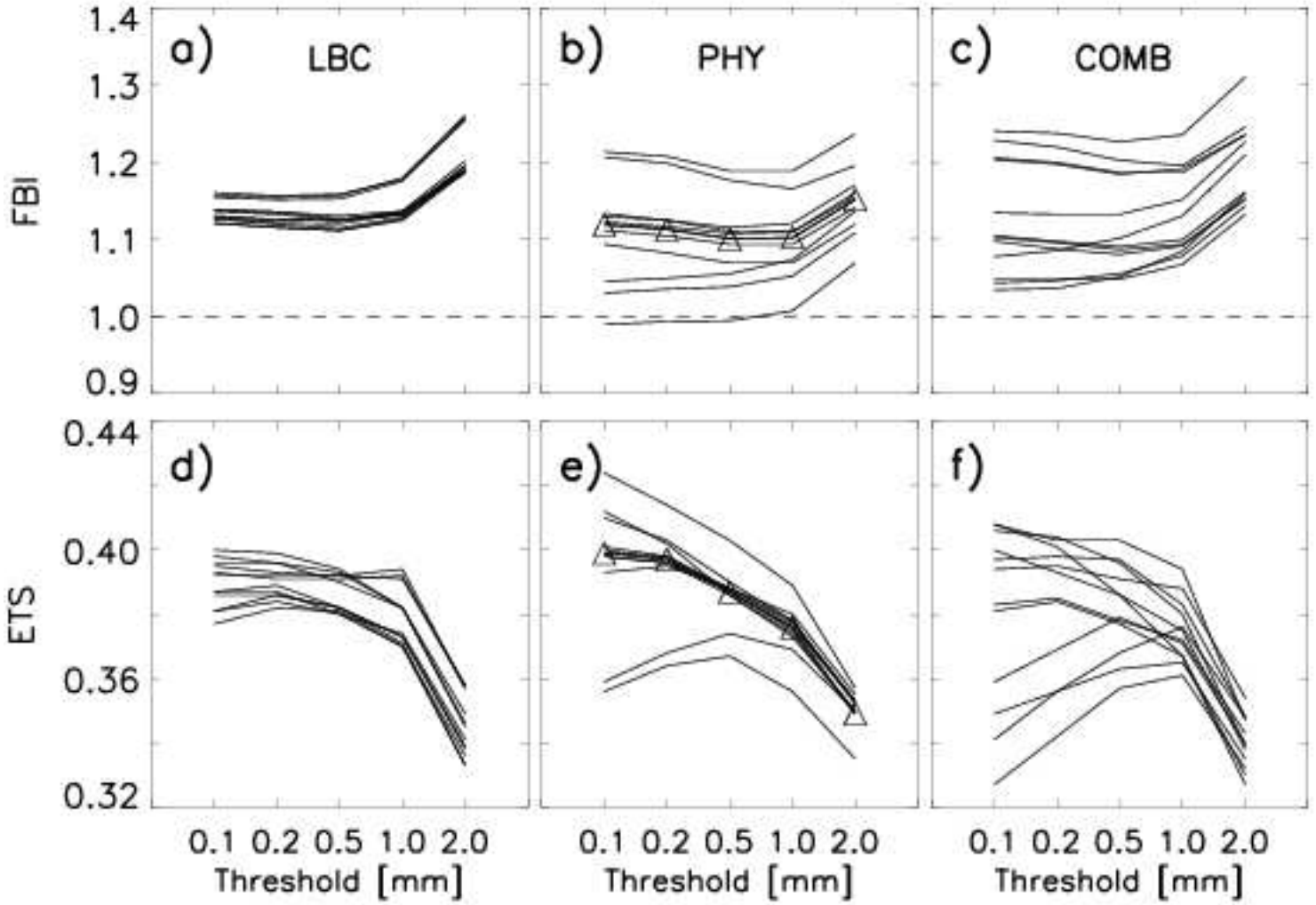
Reference Forecast:
Climatology from Period

Verification results: single member quality check



- **Frequency Bias Index**
- **24 hours accumulated precipitation**
- **red line shows the deterministic COSMO-DE**

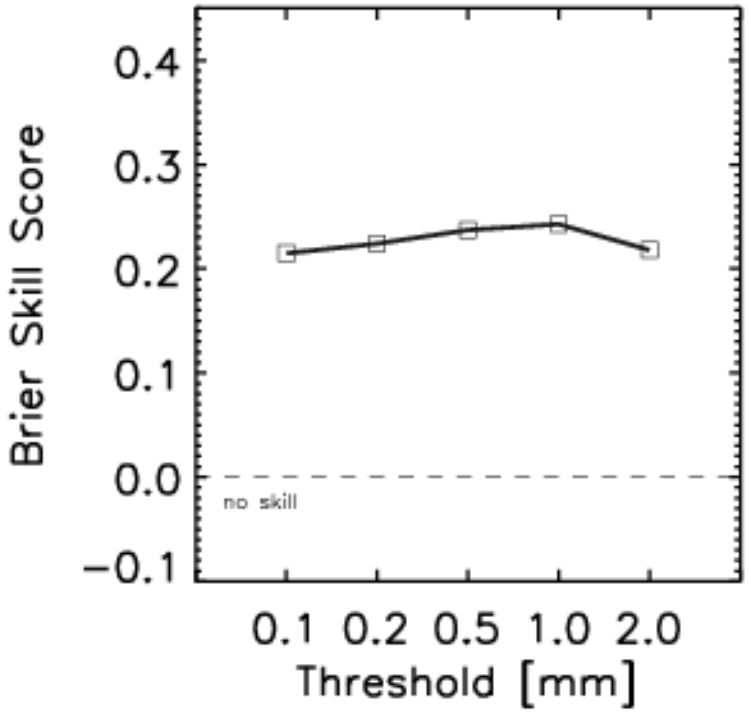
- **all members are within a reasonable range**


a) LBC
b) PHY
c) COMB
d)
e)
f)
FBI
ETS
1.4
1.3
1.2
1.1
1.0
0.9
0.44
0.40
0.36
0.32
0.1 0.2 0.5 1.0 2.0
Threshold [mm]

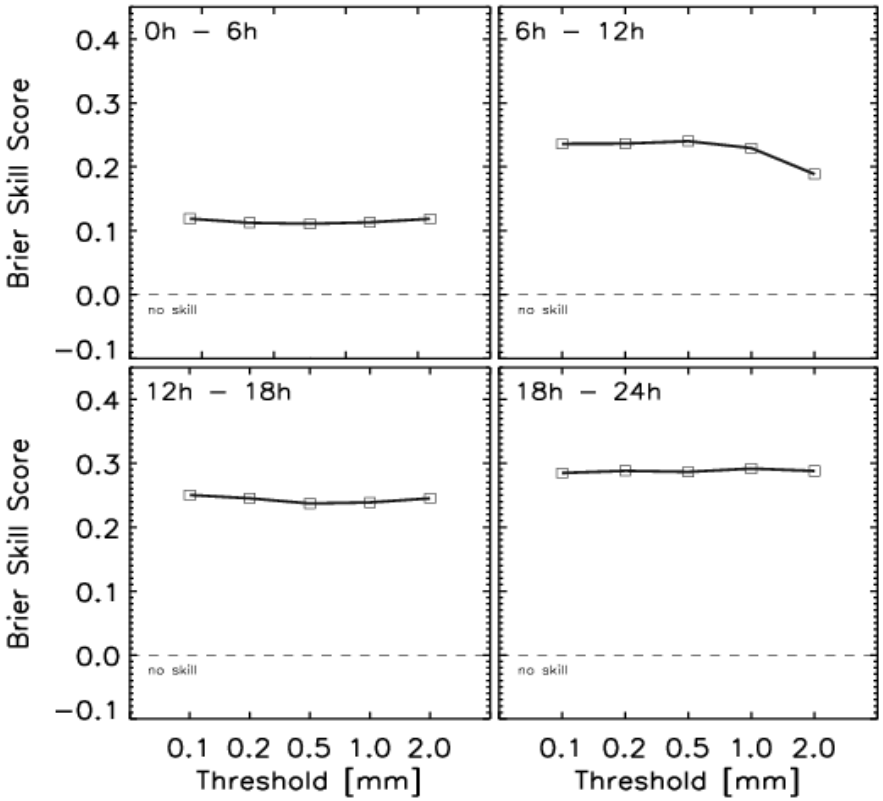
Verification results: Brier Skill Score

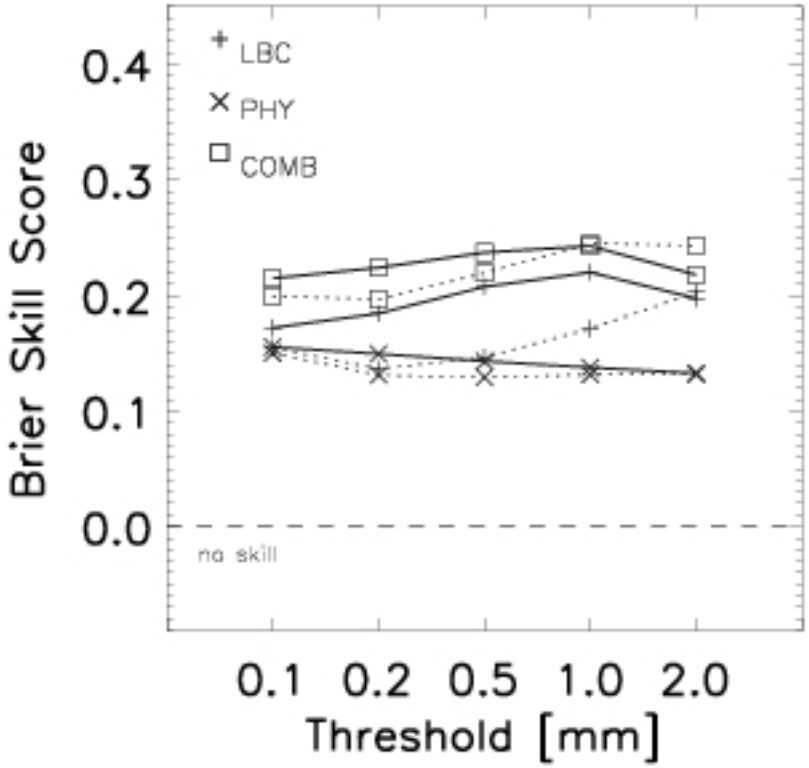
24 hours accumulated precipitation

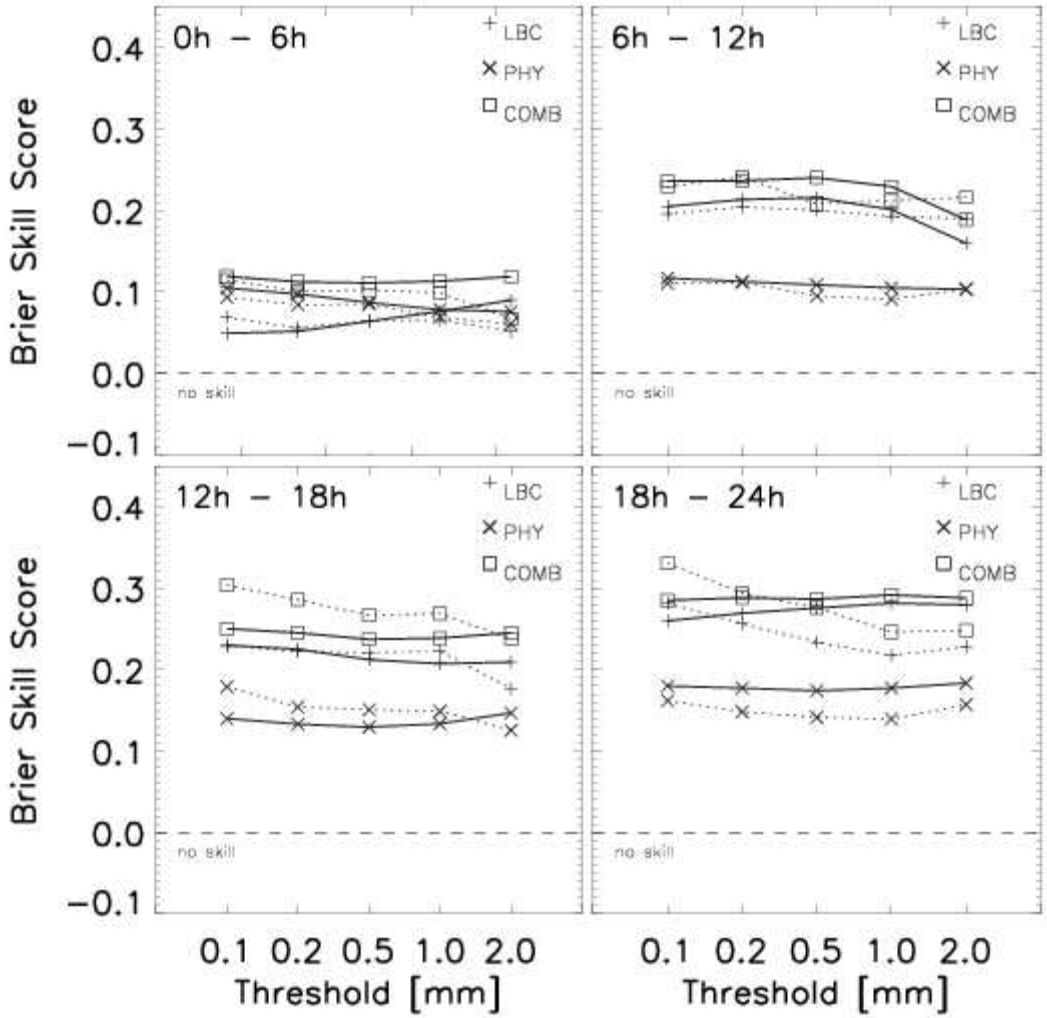
reference: deterministic COSMO-DE

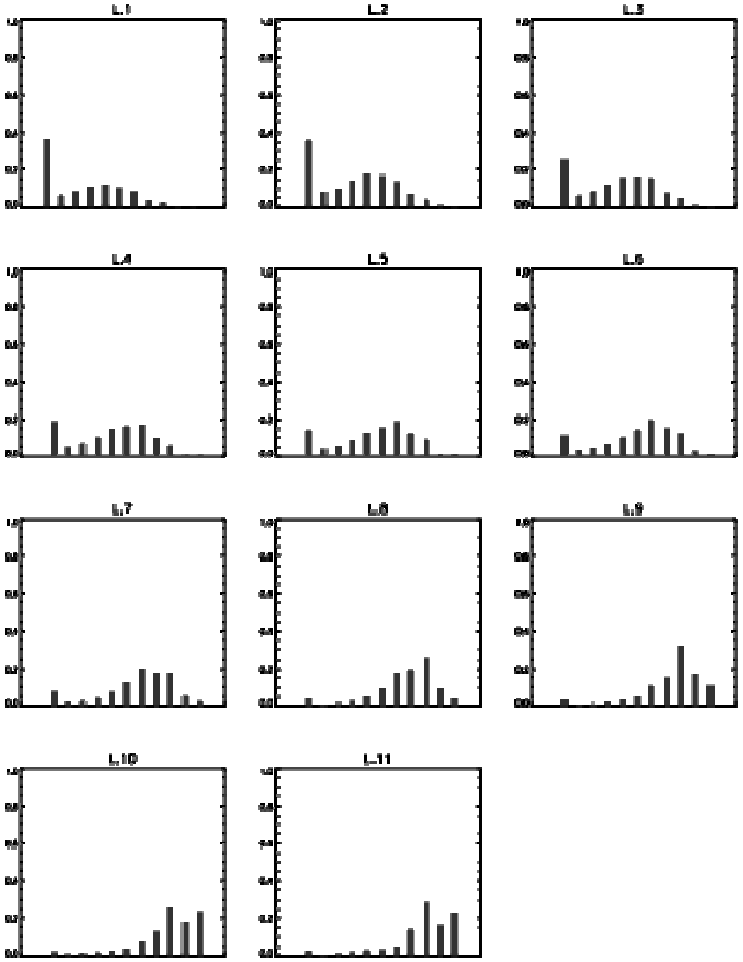


6 hours accumulated precipitation

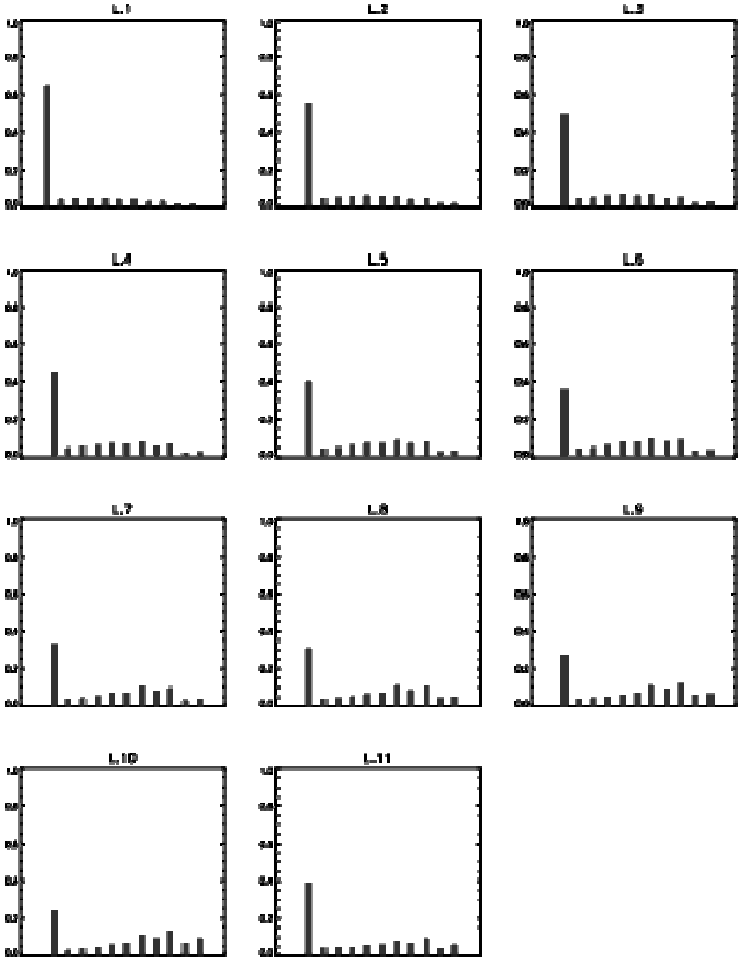



LBC
PHY
COMB
Brier Skill Score
0.4
0.3
0.2
0.1
0.0
no skill
0.1 0.2 0.5 1.0 2.0
Threshold [mm]

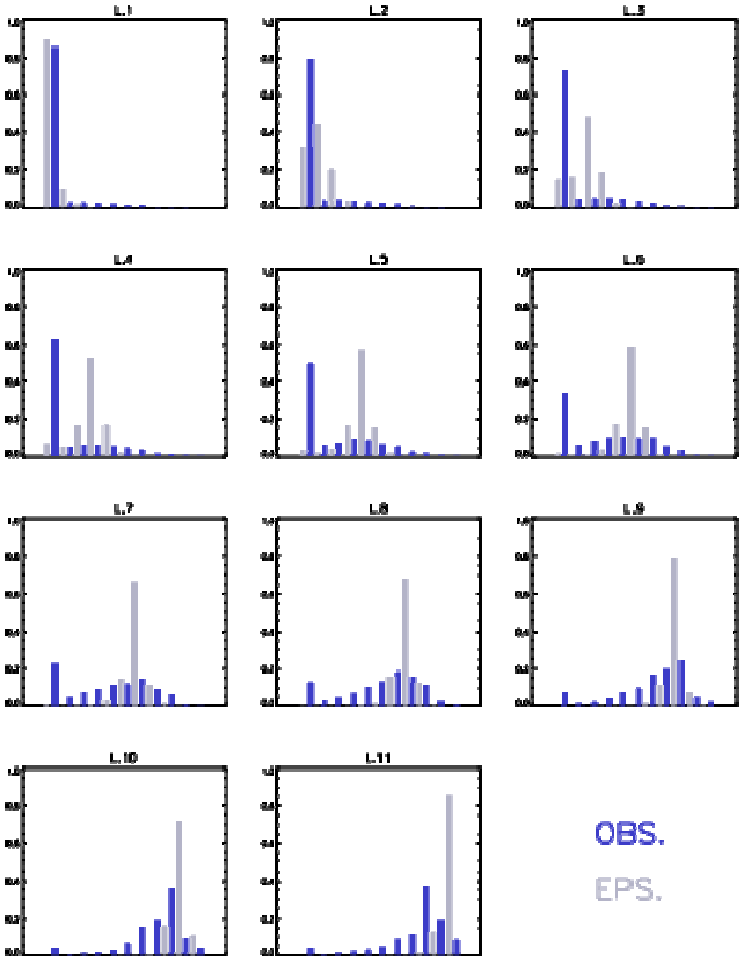

0h – 6h
6h – 12h
12h – 18h
18h – 24h
LBC
PHY
COMB
no skill
Brier Skill Score
0.4
0.3
0.2
0.1
0.0
−0.1
0.1 0.2 0.5 1.0 2.0
Threshold [mm]

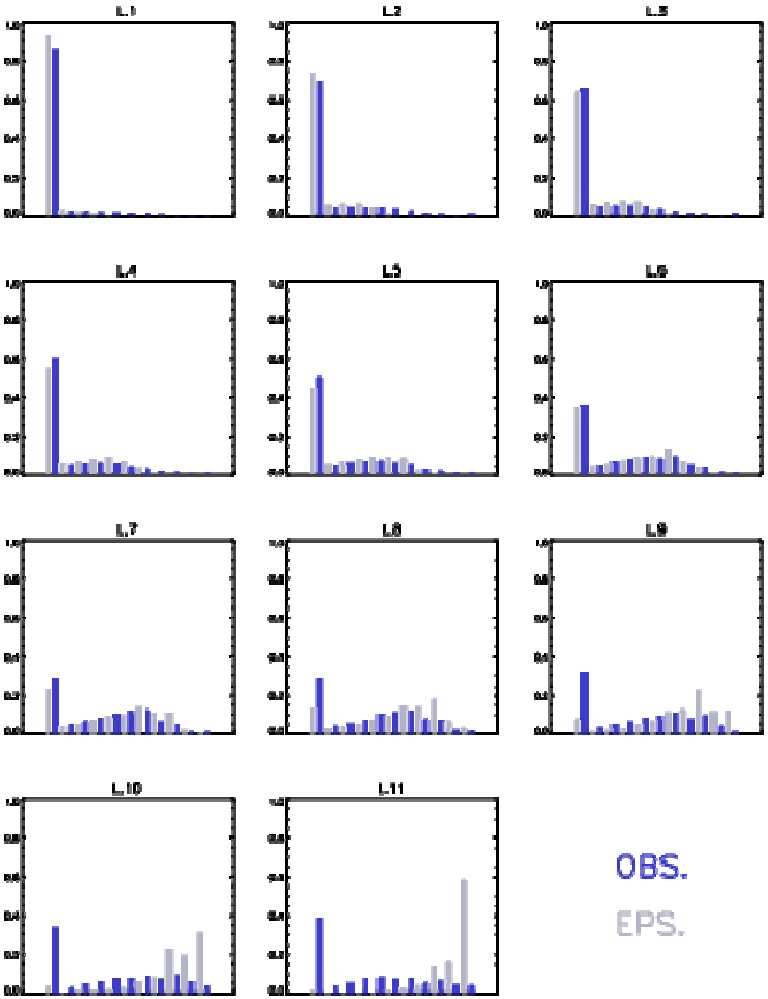


EPS. in fct of OBS. Category



EPS. in fct of OBS. Category

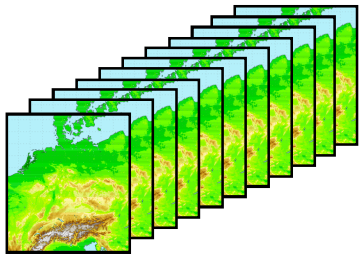

OBS.
EPS.


L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
L11
OBS.
EPS.

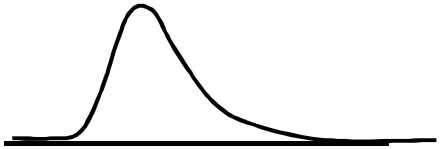
Statistical Postprocessing

Statistical Postprocessing

„variations“ in prediction system



several predictions
= „members“ of ensemble



ensemble products:

- probability density fct
- exceedance probs
- quantiles
- „spread“
- mean
- ...

Aim: improve quality
Focus: precipitation

Statistical Postprocessing

Methods:

1. Logistic Regression

→ calibration of probabilities

+ spatio-temporal neighbourhood

+ lagged average ensemble

enhance sample

2. Bayesian Approach

cooperation with University of Bonn

→ entire pdf

Reaching the User

Reaching the user (= “serve mankind”)

- make ensemble forecast **accessible**
- choose a **good format** and reduce information

- work towards **acceptance**
- work towards **correct (useful) interpretation**
- work towards integration into **decision making**

- **increase trust** in forecast provider

Visualization in NinJo

- make forecasts accessible

- choose formats

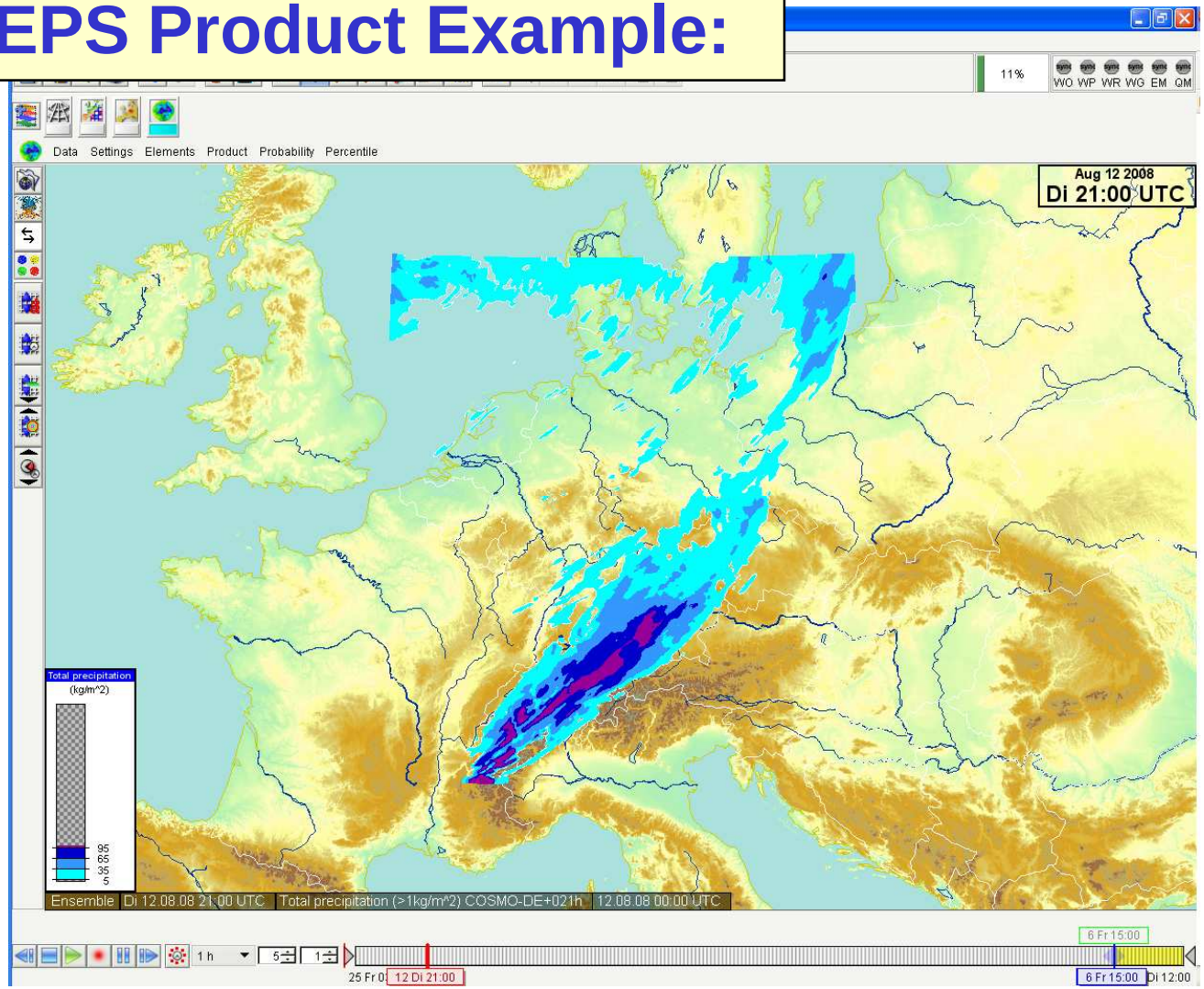
Visualization in NinJo

NinJo = visualization tool for forecasters

Challenge:

- amount of data
- good communication of complex matters
- must fit into an existing system (NinJo)

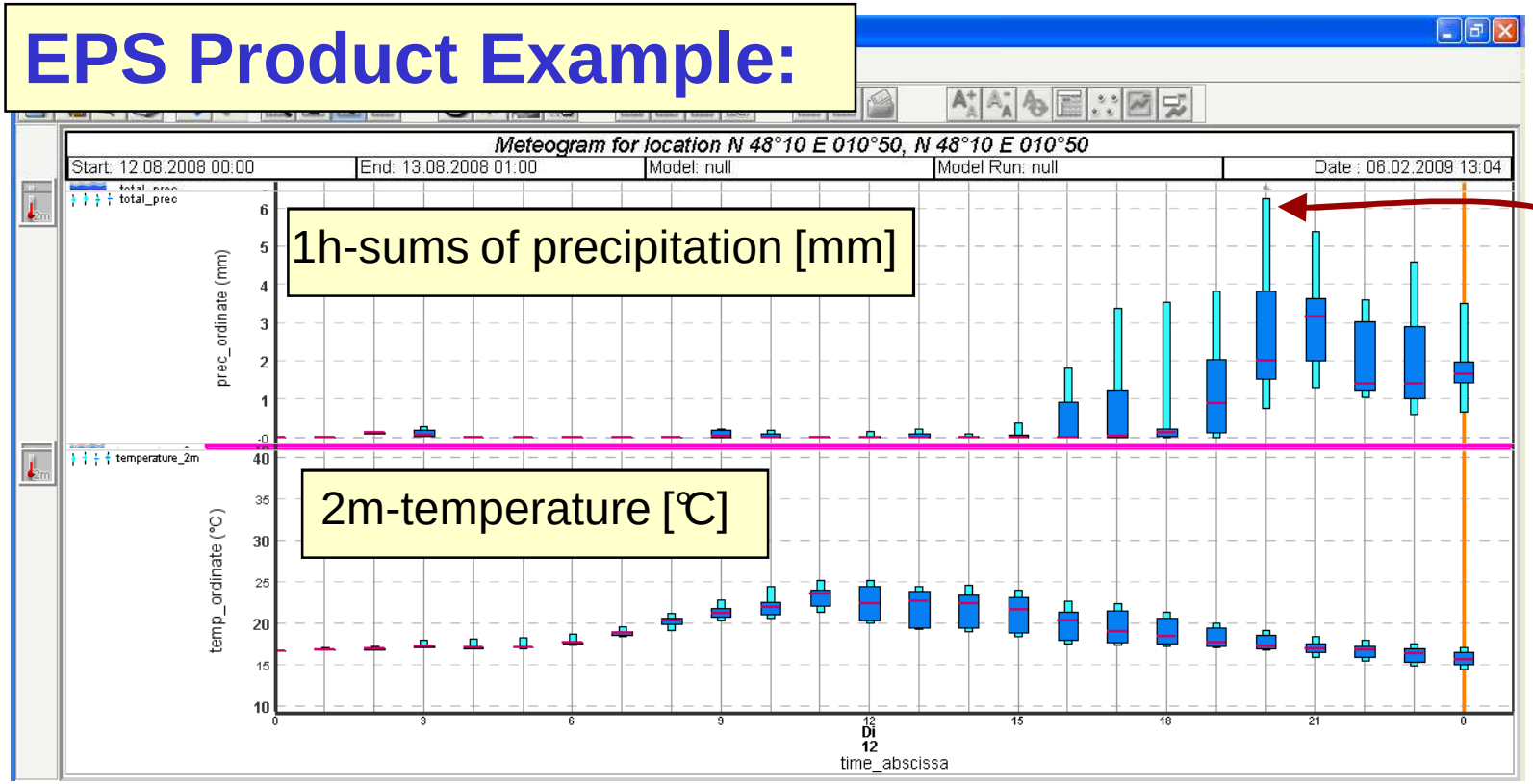
EPS Product Example:



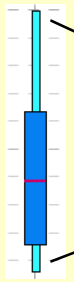
Exceedance Probabilities in %

Probability of RR > 1 mm/h

EPS Product Example:



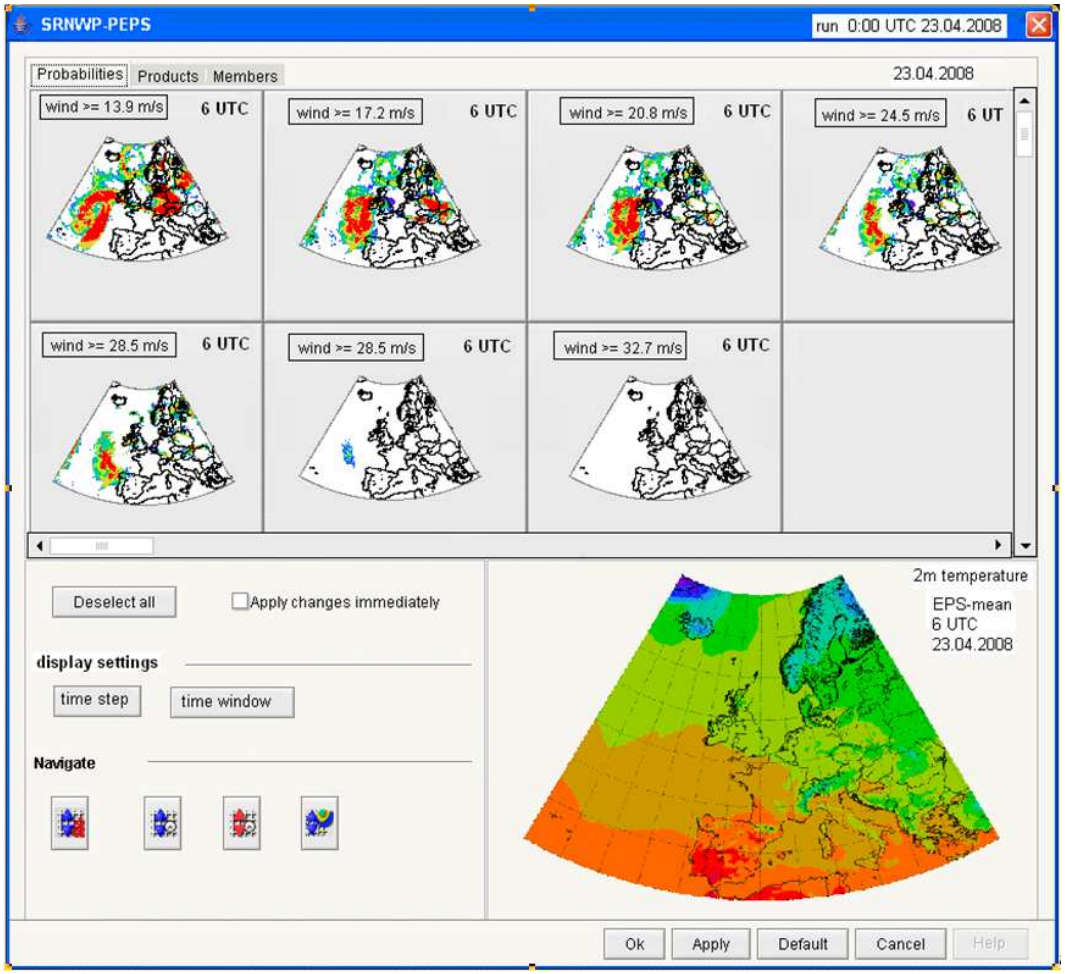
Quantiles



range of
80% probability
(= uncertainty)

10% probability (= risk)

Further Plans: Ensemble Navigation Window (draft)



also possible to
look at individual members